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INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mī' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g
a	annum, year	

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 9, Number 12, December 1968

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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Reports

Cesium–137 Concentrations in Alaskans During the Spring of 1967

Henry J. L. Rechen, Richard L. Mikkelsen, O. Glen Briscoe, and *John F. Steiner, Jr.*[1]

During April and May 1967, cesium–137 concentrations were measured by the National Center for Radiological Health, Public Health Service, in 1,334 residents of 13 Alaskan villages and cities where caribou and reindeer are major sources of meat. Unshielded 7.5 x 7.5 cm NaI (Tl) scintillation detectors, held in the lap, were used for subjects of both sexes, from 4 to 91 years old, weighing 16 to 100 kilograms. The maximum cesium–137 concentrations ranged from 16.58 to 20.76 nCi/kg for males and from 12.92 to 18.21 nCi/kg for females.

Cesium–137 concentrations were highest in Ambler, Selawik, Noorvik, Shungnak and Anaktuvuk Pass, intermediate in Shishmaref, Noatak, Mekoryuk, Egegik and Teller, and lowest in three coastal cities where whaling is done (Wainwright, Point Hope and Barrow).

The Bureau of Indian Affairs (BIA) school lunch program, where used, did not appear to reduce significantly the cesium–137 concentrations in children. Average concentrations in men who were measured both years at Anaktuvuk Pass dropped 37.5 percent from 1966 to 1967; Selawik males showed a 15.7 percent decrease, while cesium–137 concentrations in adult male residents of Egegik increased 2 percent.

The "radiation dose index" defined in this report, for the highest individual value measured in 1967 was 0.17 rad/annum. The individual was an 82 kg man whose cesium–137 concentration was 21 nCi/kg. The guidance published by the Federal Radiation Council suggests that, while surveillance should be continued, no protective action appears to be necessary at this time.

Concentrations of radioactive cesium are regularly found in Alaskans whose major sources of foods include caribou and reindeer. The use of these animals for food is not confined to the Eskimo and Indian native populations. Because of the economy, availability of indigenous foods and diet preferences of the individuals, the highest reported rates of consumption occur in the inland native villages that have few other abundantly available foods for considerable periods of each year.

The National Center for Radiological Health (NCRH), Public Health Service (PHS) has periodically measured radioactive cesium in Alaskans to define the sizes and locations of the populations having significantly higher radiation doses to establish, if possible, year-to-year trends in the dose indices, and to provide a technical basis for calculating population dose indices for radioactive cesium for comparison with recommended radiation protection guides published by the Federal Radiation Council (*1*).

Studies of the radionuclide concentrations in arctic ecosystems in Alaska were begun in 1959 as a part of the Project Chariot Environmental Program (*2*). During the summer of 1962, a

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transportable whole-body counter (*3*) was used to examine 703 Eskimos and 78 non-native residents at Barrow, Point Hope, Kotzebue and Anaktuvuk Pass (*4*). Cesium–137 was the most important fallout radionuclide detected in the subjects examined. Similar reports have been published of measurements made in Canada, Norway, Sweden, Finland, and the Union of Soviet Socialist Republics (*5–9*).

In 1962, Palmer and Perkins found cesium–134 in Alaskan Eskimos and in fallout (*10*). A similar finding for Swedish Lapps had been made by Liden and Andersson in March 1961 (*11*). The presence of detectable concentrations of cesium–134 in humans can be significant, particularly during times of reduced testing of nuclear devices in the atmosphere because it might indicate contamination of the human diet with recently-formed fallout. Cesium–134 has a physical half-life of 2.05 years as compared to the 30.76 year half-life of cesium–137.

After 1964, investigations have centered largely about three Alaskan native villages, Ambler, Anaktuvuk Pass, and Arctic Village (figure 1). Hanson had chosen the three inland villages for detailed study (*4*).

In the spring of 1965, whole-body measurements of 180 adult male patients and staff at 6 PHS Indian Health Hospitals in Alaska were made with an unshielded counter (*12*). Similar measurements were again made in the spring of 1966 at 7 Indian Health Hospitals, 2 other hospitals, and at three villages: Egegik, Anaktuvuk Pass, and Selawik (*13*). In all, 418 adult male subjects were measured, some of whom were local residents and not patients or staff at hospitals. Forty-nine men were counted both in 1965 and 1966, and there was reported to be an average decrease of 50 percent in whole-body cesium–137 content.

Cesium–137 body burdens in adults at Anaktuvuk Pass appear to have decreased since

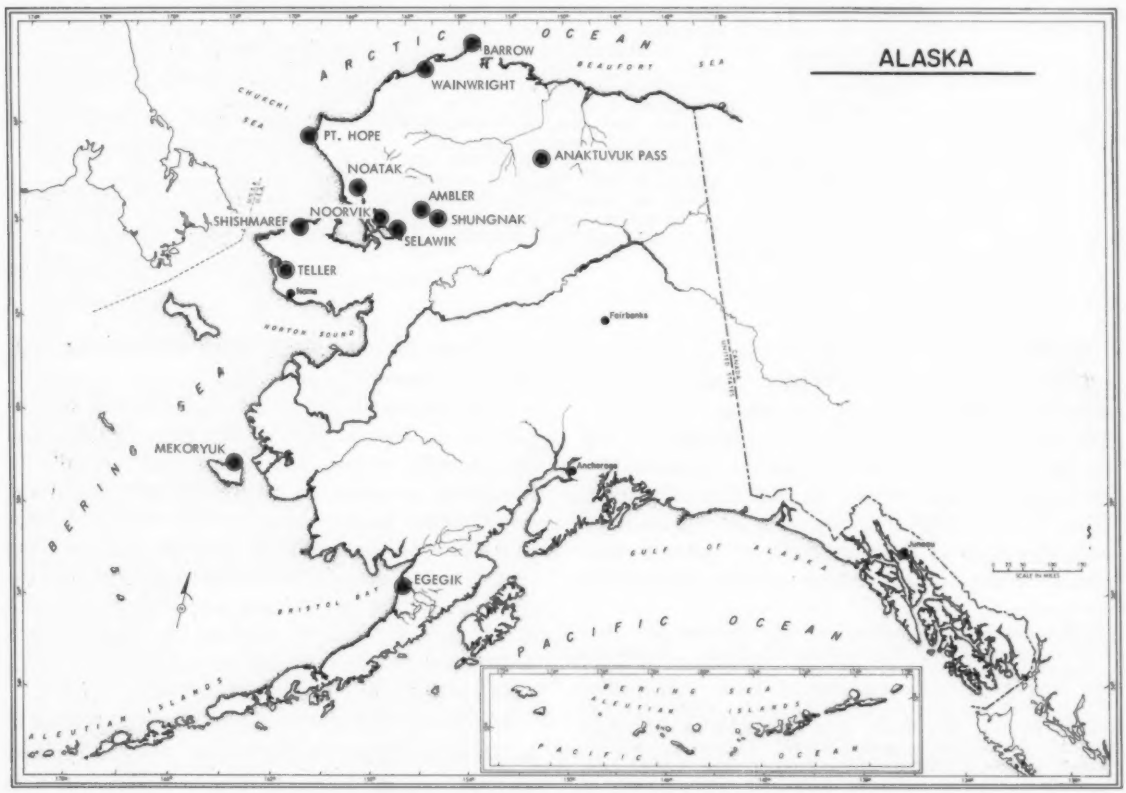

Figure 1. Alaska locations for whole body counting, April–May 1967

1964 (*14*), as have those of the higher coastal villages. Few data are available for the inland villages after 1964 (*15*), except for Hanson's reports on Ambler, Anaktuvuk Pass and Arctic Village. In 1966, the maximum values were found in residents of Selawik (*13, 16*). Because of the small numbers of individuals measured at any single place of residence, meaningful statistical conclusions have been difficult to make.

As a consequence the 1967 investigation by the NCRH was enlarged considerably in scope over those of 1965 and 1966. Counting locations were selected on the basis of community survey data furnished by the Alaska Department of Health and Welfare and by the Division of Indian Health, PHS, and included several villages in which large numbers of people ate appreciable quantities of caribou and reindeer. The object was to count as many people as possible at each location to establish a large statistical base for intervillage and time-sequential comparisons.

Measurements were made during mid-April to mid-May, at which time most of the village residents were still at home and had not yet departed for summer fishing or work areas. Many were about to make the transition from winter diets high in radiocesium (caribou and reindeer) to spring and summer diets (more abundant in fish, whales, and processed food) lower in radiocesium.

Plans were made to count subjects of both sexes and of all ages weighing over 15 kilograms who were capable of holding a detector and sitting quietly for 10 minutes.

Counting procedures

The technique of Palmer (*17*) was used with two detectors so that two subjects could be counted simultaneously. Both subjects, separated by about 4 meters, were comfortably seated, forearms on thighs, bent over unshielded 7.5 x 7.5 cm NaI(Tl) crystal and phototube detectors held on their laps with holders designed to keep the thighs together. Ten-minute counts were taken using 200 channels for each spectrum at 10 keV per channel in a multichannel pulse-height analyzer. Punched paper tapes of each spectrum were made. Duplicate tapes were mailed to the laboratory at NCRH for computer analysis.

Field estimates of cesium–137 content (nCi) were made for each pair of subjects immediately after counting and the results were given to the subjects at their request. The full spectra were examined and the subject recounted if the spectra appeared abnormal. Anomalies might easily result from power supply variations, gamma radiation from radium-painted watches, compasses and jewelry or from damage to the detectors. Occasional unshielded backgrounds without subjects were taken as were operational backgrounds using team members as phantoms. The cesium–137 content of two of the team members, 3 and 7 nCi, had previously been measured in the whole-body counter at the U.S. Naval Medical Center in Bethesda, Md. The average of the backgrounds for the two team members in each location was subtracted from the gross counts of the other subjects and 5 nCi were added to the subjects' values to correct for the subtractive step. Tests at NCRH with different weight human subjects had shown that the amount of background to be subtracted from each count was essentially constant and was, within statistical limits, independent of the sex and weight of the subject. The background that was subtracted included the contribution of potassium–40, both from the subject's body and from his surroundings, to the cesium–137 spectral region.

In scintillation counting, cesium–137 has its useful gamma photopeak at 0.662 MeV (*18*). The cesium–137 content (nCi/kg) of the subject was obtained by:

(1) adding the spectral areas, in counts, believed to represent 0.59 to 0.73 MeV;

(2) subtracting background;

(3) dividing by the counting time to give net counts per minute (CPM);

(4) multiplying CPM by the counter calibration factor (nCi/CPM);

(5) adding 5 nCi, to correct for the subtraction of the unavoidable cesium–137 content of the human "background phantom";

(6) dividing the body content (nCi) by the subject's weight (kg).

Table 1. Physical characteristics of calibration phantoms, 1967

No.	Type: Composition	Dimensions: Weight (kg)	Height (meters)	(Wt.)/(ht.²) (kg/m²)	Radioactivity content: Cesium-137 (nCi)	Cesium-137 (nCi/kg)	K-natural (g)	K-natural (g/kg)	Detector calibration factors for cesium-137: Crystal No. 1 (nCi/CPM)	Crystal No. 1 (nCi/kg-CPM)	Crystal No. 2 (nCi/CPM)	Crystal No. 2 (nCi/kg-CPM)	Average of 1 and 2 (nCi/CPM)	Average of 1 and 2 (nCi/kg-CPM)
1	Water:------	17.25	1.020	16.3	0.00	0.00	32.68	1.90						
2		17.25	1.020	16.3	157.50	9.14	32.68	1.90	0.0853	0.00495	0.0921	0.00523	0.08776	0.00509
3		33.70	1.275	16.3	.00	.00	66.12	1.96						
4		33.70	1.275	16.3	314.06	9.32	66.12	1.96	.1377	.00408	.1433	.00425	.1405	.00417
5	Sugar:------	63.60	1.65	14.2	.00	.00	-------	-------						
6		63.60	1.65	14.2	156.5	2.46	-------	-------	.2398	.00377	.2310	.00363	.2354	.00370
7		63.60	1.65	14.2	1,939	30.45	-------	-------	.2292	.00360	.2385	.00375	.2339	.00368
8		72.75	1.72	14.3	.00	.00	-------	-------						
9		72.75	1.72	14.3	180.4	2.48	-------	-------	.2606	.00358	.2527	.00347	.2567	.00353
10		72.75	1.72	14.3	2,215	30.45	-------	-------	.2363	.00323	.2223	.00305	.2339	.00315
11		81.80	1.80	14.0	.00	.00	-------	-------						
12		81.80	1.80	14.0	204.2	2.50	-------	-------	.2696	.00330	.2428	.00297	.2562	.00314
13		81.80	1.80	14.0	2,408	29.45	-------	-------	.2465	.00301	.2557	.00312	.2511	.00307

During computer analysis, a search was made for the highest 3-channel sum over a range of 4 channels, to find the cesium–137 gamma-ray peak in the spectrum and to locate the 15 channel portion of the spectrum to be summed. One out of each 10 spectra was plotted and examined for evidence of cesium–134 at 0.80 MeV (*19*). All results reported are derived from the computer analysis although field estimates were usually within 10 percent. Potassium–40 cannot be measured by this technique because the subject's body substitutes approximately as many gamma-ray counts in the potassium spectral region (*20*) as it removes from background by shielding.

No data are available to allow assignment of statements of overall statistical accuracy to the values reported for the cesium–137 determinations except for counting statistics because cross-calibration has not been done with human subjects having accurately known cesium contents in the ranges studied.

Calibration

The detectors were calibrated at the NCRH laboratory with thirteen water or sugar phantoms of five different weights, each arranged in the field counting position. Five of the phantoms did not contain cesium–137 and were used to measure background, duplicating in form those that contained cesium–137.

The water phantoms were contained in one liter or fractional liter thin-plastic bottles, cubical and cylindrical in shape. Measured amounts of potassium chloride (KCl), stable cesium chloride (CsCl), and radioactive CsCl from an Amersham standard were dissolved in deionized, distilled water. The accuracy and spectral purity of the cesium–137 and potassium–40 contents were checked by measurements of aliquots with a large shielded NaI scintillation counter and a 200-channel pulse height analyzer. The cesium–137 standard, in comparison with previous laboratory calibrations was within 5 percent of the expected value.

The sugar phantoms were assembled from 2-pound paper bags of commercial granulated sugar, having identical cesium–137 sources taped to each bag. Measurements were made with the source side of each bag facing toward and away from the detectors and the results were averaged.

A smooth function was fitted to the average calibration factors listed in table 1, and was found to be:

$$\frac{\text{nCi}}{\text{CPM}} = 0.012\ (\text{W})^{0.7} \qquad 1967\ (1)$$

$$\frac{\text{nCi}}{\text{kg-CPM}} = \frac{0.012}{(\text{W})^{0.3}} \qquad 1967\ (2)$$

where nCi = total cesium-137 in phantom, nanocuries;

$\frac{\text{nCi}}{\text{kg}}$ = concentration of cesium-137 in phantom, nCi/kg;

CPM = sum of net counts per minute in channels corresponding to gamma energy from 0.59 through 0.73 MeV;

W = weight of phantom, in kilograms.

Equations (1) and (2) were used to calculate the cesium–137 body contents and concentrations of all Alaskans counted during April and May 1967.

The data obtained in April and May 1966 (the basis for reference *13*) were recalculated using a similar function for the slightly less sensitive detector that was used. Equations (3) and (4) were derived for recalculation of the 1966 data:

$$\frac{\text{nCi}}{\text{CPM}} = 0.0134\ (\text{W})^{0.7} \qquad 1966\ (3)$$

$$\frac{\text{nCi}}{\text{kg-CPM}} = \frac{0.0134}{(\text{W})^{0.2}} \qquad 1966\ (4)$$

The use of similar equations is possible because the detector used in 1966 was physically the same as those used in 1967 except for a slight difference in housing and in resolution.

The average for the two 1967 detectors was used in developing equations (1) and (2).

Of the 1,334 subjects whose cesium–137 concentrations were measured, only 55 had net counting rates (CPM) in the 95-percent confidence interval, that were measured with a precision less than ± 10 percent because of random counting statistics. Of the 55 cases, 38 had a precision of estimate between ± 10 and ± 30 percent, 10 between ± 30 and ± 100 percent, and 7 were indistinguishable from zero (*21*).

Because counting statistics were not a major factor in the precision of the averaged results, they were not included in subsequent tabulations.

Interviews

Each subject was interviewed just before counting, and height (± 1 cm) and weight (± 1 kg) were measured.

Diet pattern interviews were made but did not give data sufficient to place any absolute value on the subject's cesium content, even within wide ranges. The results of the diet statements are not analyzed in this report.

Approximate village census data, provided by the BIA school or the village councils, were used to estimate the degree to which we were able to sample each population group. Participation was entirely voluntary.

Classification of data

For purposes of averaging individual results, the resident population counted in each village was divided into six groups by sex and weight. Weight groups were: 16–45 kg, 46–65 kg and >65 kg.

Weight groups, rather than age groups, were chosen because the formula used for calculating average radiation dose requires that average body weight but not age, be known. Age becomes a factor when genetically significant dose estimates are attempted. The latter calculations require detailed knowledge of fertility and of the sizes of the population groups interacting to form genetic "pools". The present study was designed to collect preliminary information that might be used to judge the need for more detailed studies and their scope. A second reason for using weight groups was to obtain a smooth distribution of data for intervillage comparisons. In many of the villages, key age groups are missing because of attendance at high school, mortality during epidemics, and other factors such as emigration or perhaps unusual birth ratios of the sexes.

With the two exceptions (reporting by weight group rather than by age, and not being able to measure potassium concentrations), Miettinen's criteria for reporting intercomparable data are met (*22*).

Results of counting

Figure 1 shows the 13 locations at which whole body counting for radiocesium was performed on 698 male and 636 female subjects from mid-April to mid-May 1967. Except for only two persons, the counting locations were also the residences of all of the subjects. The estimated total population of the 13 villages and cities was 2,633 male and 2,395 female. Barrow, where only 47 persons were counted, was estimated to have 1,800 residents.

Table 2 contains the average and maximum concentrations of cesium–137 measured in 1967. No spectrum examined showed evidence of cesium–134. Table 3 contains the similar data obtained by Fitzpatrick in April–May 1966,

Table 2. Average and maximum concentrations of cesium–137 in Alaskans by place of residence, 1967

Location and date (1967)	Sex and approximate population [a]	Weight range (kg)	Number counted	Average height [b] (cm)	Average weight [b] (kg)	Average year born	Cesium-137 concentrations		Ratio: maximum to average
							Average (nCi/kg)	Maximum (nCi/kg)	
Ambler	Male	16–45	19	132	29	1958	8.39	13.99	
4/22–23	69	46–65	9	168	58	1944	9.97	16.84	
		>65	13	172	77	1925	10.97	20.76	
	Female	16–45	17	131	30	1957	8.10	13.80	
	72	46–65	20	158	57	1937	9.09	17.47	
		>65	8	162	72	1928	4.88	7.28	
Anaktuvuk Pass	Male	16–45	4	138	34	1956	3.92	5.52	
5/3	65	46–65	9	138	60	1938	8.86	18.49	
		>65	14	168	72	1921	8.38	17.16	
	Female	16–45	4	141	37	1951	5.70	9.42	
	50	46–65	13	155	55	1925	5.90	10.08	
		>65	2	160	73	1936	4.88	5.25	
Barrow	Male	16–45	13	134	32	1957	.33	.88	
5/4	900	46–65	9	164	55	1950	.65	1.00	
		>65	2	179	85	1938	1.01	1.31	
	Female	16–45	10	130	30	1958	.41	.75	
	900	46–65	11	154	52	1951	.57	1.57	
		>65	2	159	67	1923	.79	.94	
Egegik	Male	16–45	25	133	31	1956	2.25	7.11	
5/14–15	91	46–65	18	163	57	1938	4.21	14.05	
		>65	14	170	70	1925	2.80	7.18	
	Female	16–45	15	129	28	1958	3.16	6.84	
	87	46–65	14	156	54	1940	2.26	8.13	
		>65	4	152	74	1929	4.24	6.57	
Mekoryuk,	Male	16–45	13	131	32	1956	2.45	4.02	
Nunivak Island	171	46–65	16	161	58	1938	4.61	6.23	
5/16–17		>65	16	169	72	1927	4.65	7.71	
	Female	16–45	11	132	34	1950	2.66	6.01	
	133	46–65	22	151	57	1943	2.88	4.82	
		>65	8	154	75	1925	2.14	3.30	
Noatak	Male	16–45	24	134	31	1958	2.67	5.93	
4/18–19	105	46–65	13	164	59	1938	4.12	8.00	
		>65	34	172	75	1926	5.97	9.33	
	Female	16–45	24	134	32	1958	2.31	5.00	
	86	46–65	23	156	56	1940	3.55	5.87	
		>65	15	160	77	1919	2.62	4.41	
Noorvik	Male	16–45	23	140	35	1954	5.50	8.20	
4/20–21	252	46–65	22	163	55	1942	8.50	18.08	
		>65	35	170	73	1925	10.90	19.90	
	Female	16–45	10	139	35	1956	6.03	9.74	
	214	46–65	37	157	57	1935	6.88	14.56	
		>65	15	156	75	1917	4.34	10.42	
Point Hope	Male	16–45	12	137	34	1957	.79	1.74	
5/8–9	190	46–65	14	165	60	1937	1.48	2.88	
		>65	15	172	76	1927	1.07	1.77	
	Female	16–45	11	139	36	1953	.60	1.17	
	162	46–65	14	157	56	1939	.84	1.56	
		>65	12	158	73	1924	.78	1.50	
Selawik	Male	16–45	33	132	30	1957	3.04	16.58	
4/25–26	229	46–65	19	166	59	1929	11.39	19.30	
		>65	15	171	76	1922	9.71	17.28	
	Female	16–45	45	130	28	1957	7.85	15.62	
	216	46–65	40	155	55	1925	8.87	18.21	
		>65	14	158	78	1927	7.47	12.92	
Shishmaref	Male	16–45	22	132	30	1958	3.50	7.02	
4/28–29	132	46–65	15	163	59	1940	4.81	10.91	
		>65	25	168	77	1926	4.63	11.46	
	Female	16–45	22	132	30	1957	3.52	6.71	
	125	46–65	28	154	54	1942	3.22	6.10	
		>65	10	158	77	1932	3.17	4.43	
Shungnak	Male	16–45	29	131	29	1957	6.25	10.84	
4/23–24	93	46–65	14	165	56	1934	8.53	13.15	
		>65	13	175	74	1925	12.02	17.93	
	Female	16–45	22	130	28	1955	6.39	10.74	
	82	46–65	23	157	55	1928	6.56	12.40	
		>65	3	163	72	1912	4.29	5.87	
Teller	Male	16–45	14	135	32	1957	2.08	3.93	
4/30–5/1	166	46–65	15	164	60	1934	3.83	6.24	
		>65	9	169	75	1930	3.92	7.00	
	Female	16–45	19	135	33	1955	1.77	4.37	
	125	46–65	18	157	56	1936	2.27	6.16	
		>65	6	155	74	1923	1.58	3.38	
Wainwright	Male	16–45	21	137	35	1954	1.76	3.03	
5/5–7	170	46–65	23	163	58	1935	3.11	6.97	
		>65	45	171	73	1925	3.71	7.09	
	Female	16–45	21	136	34	1955	1.89	4.43	
	143	46–65	22	154	56	1935	1.91	4.63	
		>65	21	162	79	1928	1.48	2.63	
Total	Male	16–45	252	134	32	1956	4.20	16.58	3.95
4/18–5/17	2,633	46–65	196	164	58	1938	5.72	19.30	3.37
		>65	250	171	76	1926	6.38	20.76	3.26
	Female	16–45	231	133	32	1955	4.35	15.62	3.59
	2,395	46–65	285	156	55	1937	4.87	18.21	3.74
		>65	120	158	74	1925	3.22	12.92	4.01

[a] Taken from approximate winter census prepared by B.I.A. school or village council.
[b] In 1967, heights and weights were measured. In 1966, the individuals were asked their approximate height and weight.

Table 3. Average and maximum concentrations of cesium-137 in Alaskan males by place of residence, 1966

Residence	Weight range (kg)	Number counted	Average height* (cm)	Average weight* (kg)	Average year born	Cesium-137 concentrations		Ratio: maximum to average
						Average (nCi/kg)	Maximum (nCi/kg)	
Akutan	46–65	1	165	65	1925	0.13	0.13	
Alakanuk	46–65	1	165	54	1937	.10	.10	
Anaktuvuk Pass	46–65	3	161	59	1936	9.62	16.81	
	>65	5	169	74	1917	10.29	13.17	
Anchorage	46–65	10	166	59	1934	.34	1.09	
	>65	43	173	76	1932	.36	2.16	
Angoon	>65	1	173	78	1902	.64	.64	
Aniak	>65	1	157	68	1947	.52	.52	
Anvik	>65	1	180	79	1929	.63	.63	
Barrow	46–65	6	168	63	1939	2.25	3.79	
	>65	40	171	75	1927	2.21	5.99	
Bethel	46–65	12	162	61	1929	1.03	3.33	
	>65	20	172	75	1926	.60	2.10	
Chefornak	>65	2	169	69	1941	.25	.26	
Chignik	46–65	3	160	61	1924	1.00	1.10	
Dillingham	46–65	7	165	60	1930	1.22	5.56	
	>65	16	175	75	1933	1.63	11.81	
Douglas	>65	5	174	79	1933	.08	.14	
Eagle River	>65	1	173	70	1897	.03	.03	
Eek	>65	1	173	70	1909	.63	.63	
Egegik	46–65	12	166	59	1925	5.22	13.49	
	>65	19	171	77	1923	2.71	8.02	
Elim	>65	1	173	68	1942	1.30	1.30	
Emmonak	>65	1	183	75	1941	.09	.09	
Fairbanks	46–65	2	168	58	1936	.18	.32	
	>65	27	177	82	1933	.30	2.43	
Fort Yukon	>65	1	173	77	1908	.21	.21	
Gakona	>65	1	175	82	1933	.63	.63	
Goodnews Bay	46–65	1	160	59	1930	.12	.12	
Hoonah	>65	1	173	68	1901	.00	.00	
Iliamna	46–65	1	168	55	1901	2.38	2.38	
Juneau	16–45	1	173	44	1953	.05	.05	
	46–65	3	169	58	1934	.03	.04	
	>65	22	177	80	1934	.08	.17	
Kake	>65	2	169	78	1915	.78	1.07	
Kiana	>65	1	168	67	1939	5.25	5.25	
Kivalina	>65	1	165	79	1930	2.58	2.58	
Klawock	>65	1	170	75	1902	.49	.49	
Kodiak	46–65	1	163	64	1904	.21	.21	
	>65	1	173	82	1940	.02	.02	
Kotzebue	46–65	5	166	63	1930	3.69	7.14	
	>65	15	175	77	1924	3.23	9.69	
Kwethluk	46–65	1	152	52	1950	.25	.25	
	>65	1	160	70	1937	.42	.42	
Kwigillingok	46–65	1	160	64	1914	1.24	1.24	
Manokotak	46–65	2	167	64	1931	1.23	1.50	
Metlakatla	46–65	2	169	58	1935	.29	.35	
Naknek	>65	1	163	66	1910	8.23	8.23	
Nome	>65	1	173	70	1931	.45	.45	
Noorvik	46–65	1	163	64	1904	6.42	6.42	
Petersburg	46–65	1	173	50	1899	.38	.38	
Platinum	46–65	1	168	57	1942	.13	.13	
Point Hope	46–65	1	157	46	1952	.58	.58	
Selawik	46–65	11	166	61	1926	17.56	24.37	
	>65	22	171	73	1923	17.48	31.91	
Shishmaref	>65	1	170	77	1918	6.28	6.28	
Sitka	46–65	10	170	60	1928	.23	.76	
	>65	23	174	79	1932	.27	.62	
Sleetmute	46–65	1	160	53	1895	.14	.14	
Tanana	46–65	14	167	61	1920	.53	2.56	
	>65	16	171	74	1926	.39	1.64	
Tatitlek	>65	1	173	67	1894	.20	.20	
Unalakleet	46–65	1	173	59	1945	1.30	1.30	
	>65	1	173	66	1942	.83	.83	
Wainwright	>65	1	165	84	1918	2.25	2.25	
Wales	>65	1	173	96	1920	1.56	1.56	
Wrangell	>65	1	175	86	1924	.14	.14	
Yakutat	46–65	1	163	59	1924	.04	.04	
Total (April-May 1966)	16–45	1	173	44	1953	0.05	0.05	1.00
	46–65	116	165	60	1928	3.19	24.37	7.64
	>65	300	173	77	1928	2.45	31.91	13.02

* In 1966, the individuals were asked their approximate heights and weights.

recalculated as explained.

Table 4 is a comparison of 1967 with 1966 values for the 8 villages having residents counted both years. Table 5 is a comparison of 1967 with 1966 values for the 38 men, residing at 5 villages, who were counted both years. All except 2 lived at Anaktuvuk Pass, Egegik, or Selawik. The difficulty of obtaining the same subjects, year after year is demonstrated by the fact that in 1967, 25 men left Selawik for employment at a coastal cannery just a few days before the counting team arrived.

Table 4. Comparison of 1967 to 1966 average and maximum cesium–137 concentrations in Alaskan males by place of residence

Residence	Weight range (kg)	Number counted and year	Average height* (cm)	Average weight* (kg)	Average year born	Cesium-137 concentrations		Ratio of 1967 to 1966	
						Average (nCi/kg)	Maximum (nCi/kg)	Average	Maximum
Anaktuvuk Pass	46–65	3—1966	161	59	1936	9.62	16.81		
		9—1967	168	60	1938	8.86	18.49	0.92	1.10
	>65	5—1966	169	74	1917	10.29	13.17		
		14—1967	168	72	1921	8.38	17.16	.82	1.30
Barrow	46–65	6—1966	168	63	1939	2.25	3.79		
		9—1967	164	55	1950	.65	1.00	.29	.26
	>65	40—1966	171	75	1927	2.21	5.99		
		2—1967	179	85	1938	1.01	1.31	.46	.22
Egegik	46–65	12—1966	166	59	1925	5.22	13.49		
		18—1967	163	57	1938	4.21	14.05	.81	1.04
	>65	19—1966	171	77	1923	2.71	8.02		
		14—1967	170	79	1925	2.80	7.18	1.03	.90
Noorvik	46–65	1—1966	163	64	1904	6.42	6.42		
		22—1967	163	55	1942	8.50	18.08	1.32	2.82
Point Hope	46–65	1—1966	157	46	1952	.58	.58		
		14—1967	165	60	1937	1.48	2.88	2.55	4.97
Selawik	46–65	11—1966	166	61	1926	17.56	24.37		
		19—1967	166	59	1929	11.39	19.30	.65	.79
	>65	22—1966	171	73	1923	17.48	31.91		
		15—1967	171	76	1922	9.71	17.28	.56	.54
Shishmaref	>65	1—1966	170	77	1918	6.28	6.28		
		25—1967	168	77	1926	4.63	11.46	.74	1.82
Wainwright	>65	1—1966	165	84	1918	2.25	2.25		
		45—1967	171	73	1925	3.71	7.09	1.65	3.15
Total	46–65	34—1966	166	60	1928	8.97	24.37		
		91—1967	165	57	1938	6.32	19.30	0.71	0.79
	>65	88—1966	171	75	1926	6.64	31.91		
		115—1967	170	75	1924	5.15	17.28	0.78	0.54

* In 1967, the heights and weights were measured. In 1966, the individuals were asked their approximate height and weight.

The comparisons of values given in tables 3, 4 and 5 are most meaningful for the three villages of Anaktuvuk Pass, Egegik and Selawik. Many of the 1966 subjects who were residents of other villages were hospital patients or employees, eating non-native diets for indefinite periods of time away from home. Thirty-nine of 52 reported places of residence, in 1966, were represented by only 1 or 2 subjects each.

Table 5. Comparison of 1967 to 1966 average and maximum cesium–137 concentrations in Alaskan men who were counted in both years

Residence	Weight range (kg)	Number counted and year	Average* height (cm)	Average* weight (kg)	Average year born	Cesium-137 concentrations		Ratio of 1967 to 1966	
						Average (nCi/kg)	Maximum (nCi/kg)	Average	Maximum
Anaktuvuk Pass	46–65	2—1966	163	57	1937	12.09	16.81		
		1967	162	56	----------	6.60	7.06	0.55	0.42
	>65	5—1966	169	74	1924	10.29	13.17		
		1967	168	72	----------	6.81	10.18	.66	.77
Egegik	46–65	9—1966	165	60	1921	5.66	13.49		
		1967	160	57	----------	6.00	14.05	1.06	1.04
	>65	9—1966	173	77	1924	3.33	8.02		
		1967	169	79	----------	3.17	7.18	.95	.89
Selawik	46–65	3—1966	175	63	1920	16.86	20.33		
		1967	170	61	----------	14.25	16.15	.85	.79
	>65	8—1966	171	73	1928	11.84	17.30		
		1967	172	75	----------	9.98	14.49	.84	.84
Noorvik	46–65	1—1966	163	64	1904	6.42			
		1967	160	52	----------	9.68		1.51	----------
Point Hope	46–65	1—1966	157	46	1952	.58			
		1967	168	54	----------	.42		.72	----------
Total	46–65	16—1966	166	60	1922	8.30	20.33		
		1967	163	57	----------	7.50	16.15	0.90	0.79
	>65	22—1966	171	75	1923	8.02	17.30		
		1967	169	76	----------	6.48	14.49	0.81	0.84

* In 1967, the heights and weights were measured. In 1966, the individuals were asked their approximate height and weight.

Interpretation of 1967 results

The summary at the end of table 2 gives the average cesium–137 concentrations, by sex and weight group, for all persons counted in April and May 1967. Five villages and cities, (Ambler, Selawik, Noorvik, Shungnak and Anaktuvuk Pass) had averages about 1½ to 2 times the overall average concentrations. These were estimated to contain 27 percent of the total population of the 13 locations where counting was done. The five communities are inland river villages and depend on hunting for meat (particularly caribou and moose), with practically all fishing being done in the summer and fall.

Five other villages, Shishmaref, Noatak, Mekoryuk, Egegik, and Teller, contain about 24 percent of the total population of the 13 locations where counting was done in 1967. The average concentrations for individuals in these communities ranked slightly below the overall averages. These communities have free access to hunting or commercial sources of reindeer or caribou. However, with the exception of Noatak, they are located on or near the coast where river and estuarial fishing is practiced much of the year, where salmon may be abundant, and where sealing and walrus hunting may provide additional sources of food or income. At Mekoryuk, each head of a family may kill five reindeer annually free of charge. Egegik is a village oriented around salmon fishing and canning. Only at Egegik and Noatak can the caribou be freely hunted when they are available. Here, too, moose are an important diet element when in season, and the meat may furnish part of the cesium–137 in the total diet of some residents.

The remaining 49 percent of the population in the 13 communities are in Wainwright, Point Hope, and Barrow, three cities having the lowest average concentrations of cesium–137. The residents of these cities concentrate on whaling, sealing, and other coastal hunting in the winter. Coastal, estuarial, and river fish and birds are abundant. While caribou might be hunted directly, residents also purchased the meat in the local stores.

A fourth class of communities, shown by the 1966 data in table 3, are those in which almost no native Alaskan foods are consumed. Without exception, the average concentrations of cesium–137 in these communities seemed to be almost as low as in the remainder of the United States. These communities were not included in the 1967 sample.

The highest individual concentrations of cesium–137 were found in Selawik and Ambler, in both men and women. The highest individual body content was 1,700 nCi, in a 38 year old, 82 kg male resident of Ambler. The cesium–137 concentration was 20.76 nCi/kg.

In general, the sexes were indistinguishable in the 16–45 kg weight class, by average height, weight and age as well as by average and maximum cesium–137 concentrations. In the men, the average factors above increased slightly with increasing weight class.

In the 46–65 kg and >65 kg weight classes, the women were almost the same average age as the men although they were shorter and lighter in average weight. Average and maximum cesium concentrations in women reached a peak in the 46–65 kg weight class, lower than that for the men, and dropped for those over 65 kg in weight.

In each village the maximum individual cesium–137 concentration was usually about two times the average for each weight class, except for men >65 kg where it was 1.8 times, and for women >65 kg where it was 1.6 times. The expected minimum appears generally to be the same factor below the average as the maximum is above it except in those villages where a resident (such as a school teacher) does not eat local food and has a body concentration of cesium–137 only slightly above zero.

Determination of the effect of school lunch programs

Of the 13 communities studied in 1967, nine had schools operated by the Bureau of Indian Affairs, U.S. Department of the Interior. These 9 schools, gave each child a full meal for every noon lunch, 5 days a week, consisting of processed food, a diet presumably lower in radiocesium than the local food. The other 4 schools at Ambler, Anaktuvuk Pass, Egegik and Teller, were operated by the Department of Education, State of Alaska, and did not give noon lunches.

A comparison of data listed in table 7 was made to see if the supplementary food seemed to reduce cesium concentrations in the children relative to the adults in BIA villages. No significant overall difference was evident, perhaps because the school lunches provided only a small fraction of each child's total daily intake of food, or because the lunches of the BIA school children were not significantly different in cesium content from those of the others.

Table 6. Comparison of effect of 1967 BIA and State school diets on cesium–137 concentrations in children relative to adults

Type of school and location	Ratio of average cesium-137 concentration 16–45 kg / 46–65 kg	
	Male	Female
State school:		
Ambler	0.84	0.89
Anaktuvuk Pass	.44	.97
Egegik	.53	1.40
Teller	.54	.78
State school average ratio	0.59	1.03
BIA school:		
Barrow	0.69	0.81
Mekoryuk	.53	.92
Noatak	.65	.65
Noorvik	.65	.88
Point Hope	.53	.71
Selawik	.73	.87
Shishmaref	.73	1.09
Shungnak	.73	.97
Wainwright	.57	.99
BIA school average ratio	0.65	0.88

Comparison of 1967 with 1966 results

In the 8 communities listed in table 4, where 122 male residents had been counted in 1966 and 204 in 1967, there had been a 25 percent reduction over the past year in average cesium–137 concentrations. The individual maxima decreased approximately 33 percent.

Table 5 compares the data for 38 men residents in 5 communities who were counted both years. The overall decrease in average cesium–137 concentration was 15 percent. Each of the three principal villages counted showed a different pattern; the average concentration in men at Anaktuvuk Pass dropped by 37.5 percent; Selawik showed a 15.7 percent decrease, while the residents of Egegik showed an insignificant 2 percent increase. The maximum individual concentrations changed comparably.

Radiation dose indices

The average annual radiation dose in an Alaskan from an average concentration of cesium–137 of one nanocurie per kilogram of body weight may be estimated as:

$$r = (W^{0.3} + 4.5) \text{ mrad/annum per nCi/kg} \quad (5)$$

where W = body weight in kg, from 15 to 100 kg.

Equation (5) was derived from the dose calculations made by Miettinen (*8*) assuming that cesium–137 emitted 0.85 gamma photons per disintegration (*23*). The contribution from beta particles and conversion electrons of cesium–137 in equation (5) is 4.5 mrad/a per nCi/kg. The term, $W^{0.3}$ mrad/a, empirically describes the dose from the absorption of gamma and X rays and closely parallels the inverse of equation (2), the gamma-ray counter sensitivity. The method of dose calculation incorporates an allowance for average subject heights associated with the corresponding average weights.

"Radiation dose index", r_i, may be defined as the product of r and $A_{s,w}$;

$$r_i = rA_{s,w} = (W^{0.3} + 4.5)A_{s,w} \quad (6)$$

Where r_i = "radiation dose index" for a specific sex-weight group in a community at a specific time, in mrad/a;
r = average annual radiation dose from an average concentration of one nCi/kg, in mrad/a per nCi/kg;
$A_{s,w}$ = average cesium–137 concentration in a specific sex-weight group in a community at a spcific time, in nCi/kg.

The "radiation dose index" applies only to the date of measurement of one sex-weight group in a given community. In the absence of any other data or guides, the radiation dose index may be assumed to be equal to the average annual radiation dose from cesium–137 for individuals in the particular community group being considered. If other data are available to permit calculation of other radiation dose indices for the same or a comparable group, or for individuals from that group, the average annual radiation dose will be the sum of the radiation dose indices, each multiplied by the fraction of the year during which the index was believed to apply. In this way, ap-

proximate allowances may be made in calculating annual population doses, for example, for groups of patients, students, or workers who change residences periodically.

For each of the 13 communities surveyed in April–May 1967, radiation dose indices have been calculated from table 2 and table 3, using equation (6) for each of the six sex-weight classifications. The indices are listed in table 7. If more than 2 individuals from a community group were surveyed in 1966, the data for that year are also given in table 7.

Table 7. Radiation dose indices for cesium–137 in Alaskan communities,[a] April–May 1966 and 1967

Location	Date		Male			Female		
	Month	Year	16–45 kg	46–65 kg	>65 kg	16–45 kg	46–65 kg	>65 kg
Measured in 1966 and 1967:								
Anaktuvuk Pass	5	1966	----	76	84	----	----	----
	5	1967	29	70	69	42	46	40
Barrow	5	1966	----	18	18	----	----	----
	5	1967	2	5	8	3	5	6
Egegik	5	1966	----	41	22	----	----	----
	5	1967	17	33	23	23	18	35
Selawik	5	1966	----	138	143	----	----	----
	4	1967	59	90	79	58	70	61
Measured only in 1967:								
Ambler	4	1967	62	79	90	59	71	40
Mekoryuk	5	1967	18	36	38	20	23	17
Noatak	4	1967	20	33	49	17	28	22
Noorvik	4	1967	40	67	89	44	54	35
Point Hope	5	1967	6	12	9	4	7	6
Shishmaref	4	1967	26	38	38	26	25	26
Shungnak	4	1967	46	67	98	47	51	35
Teller	5	1967	15	30	32	13	18	13
Wainwright	5	1967	13	25	30	14	15	12
Measured only in 1966:								
Anchorage	4	1966	----	3	3			
Bethel	5	1966	----	8	5			
Chignik	5	1966	----	8	----			
Dillingham	5	1966	----	10	13			
Douglas	5	1966	----	----	< 1			
Fairbanks	5	1966	----	1	3			
Juneau	5	1966	< 1	< 1	< 1			
Kotzebue	5	1966	----	29	26			
Sitka	4	1966	----	2	2			
Tanana	5	1966	----	4	3			

[a] Values of r_i, in mrad/a, by year, sex, and weight group.

In the calculations, the following values of r were used:

Sex	Average 1967 weight (kg)	r (mrad/a per nCi/kg)
Male:	32	7.33
	58	7.88
	76	8.17
Female:	32	7.33
	55	7.83
	74	8.14

Omitted from table 7 for lack of data are the indices for at least 163 men and 97 women reported to be temporarily away from their communities of residence in 1967 (hospital patients, teenagers at boarding school, etc).

An important conclusion may be drawn from equations (2) and (6). Equation (2) states, in slightly modified form:

$$A_{s,w} = CPM/(83.3W^{0.3}), \text{ in nCi/kg}$$

and equation (6) states:

$$r_i = (W^{0.3}+4.5)A_{s,w}, \text{ in mrad/a.}$$

If the two equations are combined, we find that

$$r_i = (CPM)(W^{0.3}+4.5)/(83.3W^{0.3})$$

and, therefore,

$$r_i = (CPM)(0.012+0.054/W^{0.3}) \qquad (7)$$

where, as defined before,

r_i = radiation dose index for a specific sex-weight group, in mrad/a,

CPM = sum of net counts per minute in channels corresponding to gamma-ray energy from 0.59 through 0.73 MeV,

W = weight of subject, in kg.

For W = 16 kg, the weight of a 4 or 5-year-old child,

$$r_i = 0.0355(CPM) \qquad (8)$$

For W = 100 kg, the weight of the largest subject observed in this study,

$$r_i = 0.0256(CPM) \qquad (9)$$

If the average of the two coefficients of equations (8) and (9) is taken and rounded off (corresponding to a subject weight of 36 kg), an estimate of the "radiation dose index" may be made for all subjects from a single formula,

$$r_i = 0.03(CPM) \qquad (10)$$

The error, for subjects from 16 to 100 kg, will not exceed 17 percent and will be negligible if a well distributed sample of subjects of all sizes is taken.

Equations (8), (9) and (10) show that the average radiation dose to a person from corporeal cesium–137, as measured by a 7.5 x 7.5 cm NaI(Tl) scintillation crystal held in the lap and covered by the forearms and upper body, is almost entirely a function of the cesium–137 concentration in the body, not of the total body content of cesium–137. We have

stated that net natural background did not seem to vary with subject height, weight, or sex. This implies that at each counting location, using calibrated crystals, one can calculate a radiation dose index for a group of the residents:

$$r_i = m\left(\frac{\text{sum of gross CPM}}{n} - \text{BKGD}\right) \quad (11)$$

where m is the detector sensitivity, (mrad/a • CPM), usually 0.030–0.033 for 7.5 x 7.5 cm crystals

BKGD is the net background count rate calculated for a human subject containing no cesium–137;

r_i is the "radiation dose index" in mrad/a for the counting location;

Sum of gross CPM is the sum of the gross cesium counts per minute for all subjects;

and n is the number of subjects at the counting location.

The radiation dose index for the group can be calculated directly from the net counting data and does not involve intermediary calculations of individual cesium concentrations or knowledge of the body weights.

Summary and conclusions

During April and May 1967, cesium–137 concentrations were measured by the National Center for Radiological Health, Public Health Service, in 1,334 residents of 13 Alaskan villages and cities where caribou and reindeer are major sources of meat. Unshielded 7.5 x 7.5 cm NaI(Tl) scintillation detectors, held in the lap, were used for subjects of both sexes, from 4 to 91 years old, weighing 16 to 100 kilograms. The overall cesium–137 concentrations were:

Sex	Number of subjects	Weight range (kg)	Cesium-137 concentrations (nCi/kg)	
			Group average	Individual maximum
Male	252	16–45	4.20	16.58
	196	46–65	5.72	19.30
	250	>65	6.38	20.76
Female	231	16–45	4.35	15.62
	285	46–65	4.87	18.21
	120	>65	3.22	12.92

No cesium–134 was detected.

Cesium–137 concentrations were highest in Ambler, Selawik, Noorvik, Shungnak and Anaktuvuk Pass, intermediate in Shishmaref, Noatak, Mekoryuk, Egegik and Teller, and lowest in three coastal cities where whaling is done (Wainwright, Point Hope and Barrow).

The Bureau of Indian Affairs school lunch program, where practiced, did not appear to reduce significantly the cesium–137 concentrations in children. Average concentrations in men who were measured both years at Anaktuvuk Pass dropped 37.5 percent from 1966 to 1967; Selawik males showed a 15.7 percent decrease, while cesium–137 concentrations in adult male residents of Egegik increased 2 percent.

The Federal Radiation Council has discussed guidance with regard to the need for protective actions to reduce cesium–137 concentrations in Alaskans (*1*). They have concluded that the applicable Radiation Protection Guide is 0.5 rad per year because the cesium–137 in the groups of interest is being measured directly. The data given in table 7 show that comparable 1967 values were almost consistently lower than those for 1966, and in neither year did the group averages equal or exceed one-third of the Radiation Protection Guide. The highest individual values listed in table 2 (1967), 21 nCi/kg in an 82 kg man (0.17 rad/year), and table 3 (1966), 32 nCi/kg in a 68 kg man (0.26 rad/year), were below the RPG, indicating that while surveillance should be continued, no protective action is necessary at this time.

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Technical Notes

Alpha Radiation Exposure Levels in Underground Uranium and Other Mines

Bureau of Mines [1]
Department of the Interior

Surveys of radon daughter concentrations in air in underground uranium mines were begun by the Bureau of Mines in the early 1950's when the U.S. Public Health Service first warned of the potential hazard of lung cancer due to ionizing radiation.

For more than 15 years, inspections, including surveys of radon daughter concentration, have been conducted in uranium mines on Indian lands. From 1959 through March 30, 1962, when they were closed, mines on Atomic Energy Commission withdrawn lands [2] were also inspected by the Bureau of Mines. In 1961, at the request of the Industrial Commission, State of Utah, the Bureau aided in establishing a State uranium mine radiation control program. Bureau engineers and Utah State mine inspectors jointly inspected all operating uranium mines in Utah at least once.

During 1962 and 1963, under Public Law 87–300, the Department of the Interior, acting through the Bureau of Mines, was charged with responsibility for reporting to the Congress on health and safety conditions in all the Nation's noncoal mines including uranium mines. During this period, radon-daughter concentrations were measured on two occasions in each of the larger underground uranium mines and in most of the smaller ones.

Individual reports were issued covering the inspections and surveys made in this period. Table 1 summarizes the radon daughter concentrations expressed as working levels [3] found from 1959 to 1963. Prior to 1962 only working places were sampled and full-shift exposure rates were not estimated. Since 1962, full-shift exposure rates have been estimated for individual underground workers based on development of a spot-check time-weighted method (*1*) as result of a special study conducted in 10 mines during October 1960 through May 1961.

Procedure

Radon daughter sampling was performed using the conventional filtered-air method (*2*). Mine air was drawn through filter papers at a measured rate by a pump for a 5 or 10-minute period. After allowing the particulates collected on the filters to age at least 40 minutes, alpha radioactivity was measured using a calibrated scintillation-type field counter. Alpha radioactivity at the time of measurement was converted to potential alpha-particle energy at the time of sampling by dividing disintegrations per minute by the number of liters sampled and multiplying by the elapsed time factor (*2*).

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[1] Summarized from "Mineral Industry Surveys, Health and Safety Summary," prepared by the staff of the Division of Accident Prevention and Health, Bureau of Mines, Washington, D.C., May 1968, and "Mineral Industry Surveys, Health and Safety Summary" prepared by Donald K. Walker, technical assistant, Health and Safety District E, Bureau of Mines, Denver, Colo., August 1968.

[2] Lands withdrawn from the public domain for AEC use.

[3] One "working level" is defined as any combination of radon daughters in 1 liter of air that will result in the ultimate emission of 1.3 x 10^5 MeV of potential alpha-particle energy. The numerical value of the working level is derived from the alpha-particle energy released by the total decay of the short-lived radon daughter products at radioactive equilibrium with 100 pCi of radon–222 per liter of air.

Table 1. Radon-daughter concentrations found during various surveys

Survey	Number of mines	Total number of working places	Number of working places within working level range					
			0–0.3	0–1.0	0–3.0	0–5.0	1–10.0	0–10.0+
1959–61 mines on Indian land and AEC with drawn land	(1st inspection) 50	93	[a]	15 [b] (16)	33 (35)	[c]	68 (73)	93 (100)
	(2nd inspection) 33	94		37 (39)	64 (68)	[c]	82 (87)	94 (100)
	(3rd inspection) 29	86		41 (48)	56 (65)	[c]	77 (90)	86 (100)
	(4th inspection) 21	85		23 (27)	57 (67)	[c]	76 (89)	85 (100)
	(5th inspection) 19	88		22 (25)	51 (58)	[c]	80 (91)	88 (100)
	(6th inspection) 10	64		15 (23)	36 (56)	[c]	56 (88)	64 (100)
	(7th inspection) 4	13		4 (31)	8 (62)	[c]	13 (100)	—
		Estimated average full-shift exposure rates						
		Number of men exposed	Number of men exposed within working level range					
PL 87–300 (1962–63)	(1st inspection) 139	2,213	[a]	1,007 (45)	1,634 (74)	1,946 (88)	2,104 (95)	2,213 (100)
	(2nd inspection) 119	2,242	[a]	978 (44)	1,653 (74)	1,907 (85)	2,158 (96)	2,242 (100)

[a] No results in given working level range.
[b] Values in parentheses are percent of working places or men in given working level range.
[c] Data for this range of exposures was not recorded prior to 1961.

Individual samples were taken in all occupied mine areas. A time study was made to allow individual samples to be time weighted into average full-shift exposure rates for each miner or group of miners (*1*).

Detailed ventilation-radiation level studies were made in six of the larger underground uranium mines in April through September 1967. These studies were designed specifically to reveal the relationships between ventilation and working levels which existed in the mines. Each detailed study required tracing and measuring the ventilating air both quantitatively and qualitatively (for alpha radiation from airborne particulates) from the point where fresh air entered the mine to where the air was distributed in production areas and finally where return air was exhausted at the surface. Although these studies were very time consuming, after all the information was assembled, a clear picture of the relationships being sought was afforded. Conditions were described and recommendations for reducing working levels were developed (table 2).

Table 2. Summary of recommended ventilation changes to reduce radiation levels in six underground uranium mines in which detailed ventilation-radiation surveys were conducted in 1967

Recommendation	Number of times recommendation was made
Provide and maintain auxiliary ventilation	10
Eliminate recirculation	10
Seal old workings	3
Increase primary ventilation	3
Additional openings required	2
Responsibility for insuring that all fans are operating while men are underground should be designated	1

Recent survey data

On March 30, 1967, the Bureau of Mines began the latest survey of radiation exposure rates experienced by miners in all the nation's underground uranium mines. These data were collected during radiation surveys made by mining engineers of Health and Safety District E, Bureau of Mines, Denver, Colo., and the Phoenix, Ariz., and Salt Lake City, Utah subdistrict offices. Surveys were made in uranium mines in Arizona, California, Colorado, New Mexico, South Dakota, Utah, and Wyoming.

Table 3. Estimated full-shift exposure rates to radon daughters, April 1–June 30, 1967 [a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	313	28.7	28.7	71	38.0	38.0	384	30.1	30.1
0.4–1.0	336	30.9	59.6	34	18.2	56.2	370	29.0	59.1
1.1–3.0	256	23.5	83.1	57	30.5	86.7	313	24.5	83.6
3.1–5.0	89	8.2	91.3	12	6.4	93.1	101	7.9	91.5
5.1–10.0	80	7.3	98.6	9	4.8	97.9	89	7.0	98.5
>10	15	1.4	100.0	4	2.1	100.0	19	1.5	100.0
Total	1,089	100.0		187	100.0		1,276	100.0	

[a] 119 original surveys.

Table 4. Estimated full-shift exposure rates to radon daughters, July 1–September 30, 1967 [a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	202	21.5	21.5	53	39.3	39.3	255	23.7	23.7
0.4–1.0	322	34.2	55.7	30	22.3	61.6	352	32.7	56.4
1.1–3.0	351	37.3	93.0	33	24.4	86.0	384	35.7	92.1
3.1–5.0	44	4.7	97.7	8	5.9	91.9	52	4.8	96.9
5.1–10.0	22	2.3	100.0	8	5.9	97.8	30	2.8	99.7
>10				3	2.2	100.0	3	0.3	100.0
Total	941	100.0		135	100.0		1,076	100.0	

[a] 47 original surveys and 30 resurveys.

Table 5. Estimated full-shift exposure rates to radon daughters, October 1–December 31, 1967 [a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	66	25.2	25.2	50	45.9	45.9	116	13.3	31.3
0.4–1.0	154	58.8	84.0	37	33.9	79.8	191	51.5	82.8
1.1–3.0	36	13.7	97.7	21	19.3	99.1	57	15.4	98.2
3.1–5.0	6	2.3	100.0	1	0.9	100.0	7	1.8	100.0
5.1–10.0									
>10									
Total	262	100.0		109	100.0		371	100.0	

[a] 10 original surveys and 48 resurveys.

Table 6. Estimated full-shift exposure rates to radon daughters, January 1–March 31, 1968 [a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	384	36.1	36.1	30	54.5	54.5	414	37.0	37.0
0.4–1.0	421	39.6	75.7	11	20.0	74.5	432	38.6	75.6
1.1–3.0	207	19.5	95.2	11	20.0	94.5	218	19.5	95.1
3.1–5.0	35	3.3	98.5	2	3.7	98.2	37	3.4	98.5
5.1–10.0	16	1.5	100.0	1	1.8	100.0	17	1.5	100.0
>10									
Total	1,063	100.0		55	100.0		1,118	100.0	

[a] 8 original surveys and 32 resurveys.

Table 7. Estimated full-shift exposure rates to radon daughters, April 1–June 30, 1968[a]

Average exposure rates (working levels)	Mines employing more than four men			Mines employing four men or less			Total of all mines		
	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent	Number of men exposed	Percent men exposed	Cumulative percent
0–0.3	295	44.9	44.9	63	63	63	358	47.3	47.3
0.4–1.0	269	40.9	85.8	21	21	84	290	38.3	85.6
1.1–3.0	71	10.8	96.6	10	10	94	81	10.7	96.3
3.1–5.0	12	1.8	98.4	3	3	97	15	2.0	98.3
5.1–10.0	1	0.2	98.6	3	3	100	4	0.5	98.8
>10	9	1.4	100.0				9	1.2	100.0
Total	657	100.0		100	100		757	100.0	

[a] 23 original surveys and 40 resurveys.

All active underground uranium mines were surveyed once and most have been resurveyed. Not all mines were surveyed in any one quarter. The selection of mines surveyed in a period was not completely random. However, enough mines were surveyed each quarter to give an industry-wide picture.

Data collected through June 30, 1968, during original surveys and resurveys of these mines are summarized in tables 3 through 7, by quarter years for comparison purposes. The steady improvement is indicated in the quarterly results given in tables 3 through 7. Table 3 shows that full-shift exposure rates were less than one working level for 59.1 percent of the miners evaluated in the first quarter of sampling (April 1–June 30, 1967), and table 7 shows this figure increased to 85.6 percent for the last quarter sampled (April 1–June 30, 1968).

Because of the Secretary of Labor's June 12, 1967, issuance of an exposure standard of 0.3 working level month [4] for operations subject to the Walsh-Healey Public Contract Act (*3*), the data are summarized so as to allow evaluation in terms of the Secretary of Labor's standard as well as in terms of the exposure standard of 1.0 working level month tentatively recommended by the Federal Radiation Council (*4*).

Table 8 summarizes suggestions given in the initial survey reports for reducing working levels in 197 mines. Table 9 is a summary of suggested ventilation changes to reduce working levels in 136 mines surveyed twice.

[4] A working level month is defined as the exposure received by a worker breathing air at one working level concentration for 4⅓ weeks of 40 hours each.

Table 8. Summary of suggested ventilation changes to reduce alpha radiation levels in initial surveys of 197 underground uranium mines [a]

Suggestion	Number of times suggestion was recorded		
	127 mines employing four men or less	70 mines employing more than four men	Total 197 mines
Provide and maintain auxiliary ventilation	46	33	79
Eliminate recirculation and short circuiting	12	19	31
Seal old workings	31	26	57
Increase air volume by larger fan, adjustment of fan or additional fan	36	27	63
Provide mechanical ventilation	11	1	12
Additional openings required	14	28	42
Total	150	134	284

[a] This is a subjective compilation adequate only to give a broad general picture. Specific recommendations were not made in radiation survey reports; information in this table is gleaned from summary discussions in the reports.

Nonuranium mines

To determine the extent of the alpha radiation problem in mines other than uranium, radon-daughter samples have been taken in several nonuranium mines. These data are compiled in tables 10 and 11. The data listed in table 10 were collected during environmental dust surveys conducted from 1958 to 1961. The data in table 11 were collected from September 1, 1967 through May 10, 1968.

Indications to date are that current conditions in nonuranium mines are generally adequate to meet a 1.0 working level standard. However, spot sampling for radon daughter concentrations will eventually apply to all underground mines in the United States for a full assessment of the potential health problem to underground miners.

Table 9. Summary of suggested ventilation changes to reduce alpha radiation levels comparing initial surveys with resurveys of 136 underground uranium mines [a]

Suggestion	Number of times suggestion was recorded											
	74 mines employing four men or less				62 mines employing more than four men				Total, 136 mines			
	Initial survey	Resurvey			Initial survey	Resurvey			Initial survey	Resurvey		
		Adopted	Repeated	New		Adopted	Repeated	New		Adopted	Repeated	New
Provide and maintain auxiliary ventilation	31	8	15	16	32	6	25	14	63	14	40	30
Eliminate recirculation and short circuiting	10	3	3	8	18	4	4	11	28	7	7	19
Seal old workings	21	1	12	13	26	6	11	14	47	7	23	27
Increase air volume by larger fan, adjustment of fan or additional fan	26	5	12	16	27	7	11	15	53	12	23	31
Provide mechanical ventilation	4	3	-------	1	1	-------	1	1	5	3	1	2
Additional openings required	12	-------	3	5	28	7	10	5	40	7	13	10
Total	104	20	45	59	132	30	62	60	236	50	107	119

[a] This is a subjective compilation only. Radiation survey and resurvey reports do not present specific recommendations and adopted suggestions are not always reported. Information in this table was gleaned from summary discussions in the reports and is not complete.

Table 10. Radon-daughter sampling in nonuranium mines, 1958–1961

Commodity	Number of mines	Number of samples	Working levels
Chromate	1	4	< 0.1
Copper	7	22	< .1
		5	.2
		2	.3
		2	.7
		1	1.0
Gold	1	5	< .1
Gold-silver	1	3	< .1
Iron	6	20	< .1
		2	.2
		2	.3
Lead-silver	3	10	< .1
Lead-zinc	8	21	< .1
		1	.3
		4	.5
Manganese	1	3	< .1
Mercury	3	4	Nil
		6	< .1
Molybdenum	1	2	< .1
		1	.3
Pyrite	1	several	< .1
Tungsten, copper, molybdenum	1	1	< .1
		1	.8
		1	[a] 18.7
Total	34	+123	

[a] Unventilated area.

Table 11. Radon-daughter sampling in nonuranium mines, 1967–1968

Commodity	Number of mines	Number of samples	Working levels
Coal	9	53	Nil
Fluorspar	1	3	<0.1
Molybdenum	1	4	Trace
			< .1
Tungsten, copper, molybdenum	1	1	.5
		3	.4
		1	.3
		1	.1
		3	< .1
Gold	1	5	Trace
			< .1
Potash	3	9	Nil
Trona	3	3	Trace
			< .1
		16	Nil
Phosphate rock	1	1	.6
		2	.3
		3	.2
		2	.1
Clay	1	1	.2
		6	< .1
		1	Nil
Lead-zinc	2	1	.4
		1	.3
		5	.2
		5	< .1
		2	Nil
Total	23	142	

Acknowledgement

The cooperation of mining companies and their personnel in facilitating the collection of radon-daughter samples and obtaining related data is gratefully acknowledged. State inspection personnel frequently accompanied Bureau of Mines engineers during the surveys and studies and their efforts and cooperation were very helpful.

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Alpha Radioactivity in Coal Mine Drainage in Western Pennsylvania

Roger D. Caldwell, Ronald F. Crosby and *M. Paul Lockard*[1]

Most health groups at nuclear facilities, in addition to their regulatory responsibility to monitor the effluents from the facility, monitor the offsite environment. This is done to (1) determine the effectiveness of their effluent monitoring, (2) determine the level of offsite exposure and (3) provide a background base in case of an accidental release. The Nuclear Materials and Equipment Corporation (NUMEC) samples Kiskiminetas River at weekly intervals (in addition to the routine air, fallout and vegetation monitoring), as the effluent from NUMEC is emptied into this river.

The NUMEC nuclear fuel plants are located about 30 miles northeast of Pittsburgh. The Kiskiminetas River flows into the Allegheny River just north of Pittsburgh (figure 1). The plutonium plant is about 10 miles up the Kiskiminetas River near Leechburg; the uranium plant is in Apollo, 5 miles farther upstream.

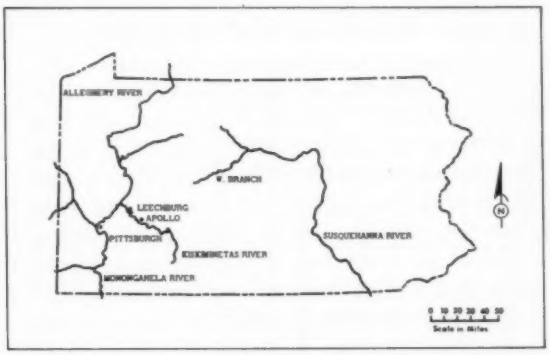

Figure 2. Physiographic divisions of Pennsylvania

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Origin of natural radioactivity in coal mine drainage

Coal mining—once the principal industry—is still an important industry in western Pennsylvania. Several authors have referred to the association between uranium and coal in mines (*1–7*). Large reserves of uranium-bearing coal and lignite are known in western North and South Dakota and southeastern Montana. In 1954, considerable tonnages of ore-grade uraniferous lignite were discovered in the Cave Hills area of western South Dakota (*6*). These western United States discoveries led the U.S. Geological Survey to explore eastern coal reserves for uranium occurrences (*2, 3*). Uranium was found in uneconomic concentrations in Pennsylvania coal. Estimates ranged from 10 to 140 parts per million, although some eastern Pennsylvania sedimentary deposits contain up to 0.3 percent U_3O_8 (*1*).

The coexistence of uranium and coal is explained by the descending meteoric hypothesis for uranium occurrences (*1*). Downward moving solutions leached small amounts of uranium and other metals from syngenetic accumulations in the overlying sediments and these metals ultimately were precipitated in carbonaceous zones by organically produced hydrogen sulfide.

Survey and analytical methods

Samples were taken from the Kiskiminetas River at three sites to determine the alpha radioactivity concentration. The sampling sites at Apollo, Leechburg, and Vandergrift are above the uranium plant, below the plutonium plant and between the two plants, respectively. The average radioactivity concentrations for 1966 are given in table 1. Since nuclear fuel radionuclides are alpha-particle emitters, only alpha radioactivity levels are reported.

Table 1. Alpha radioactivity concentrations on the Kiskiminetas River, 1966

Sampling location	Concentration (pCi/liter)		
	Minimum	Maximum	Average
Apollo	0.3	102.7	13.14
Vandergrift	.45	101.0	13.36
Leechburg	.9	46.0	10.77

The average gross alpha-particle concentrations observed in the Kiskiminetas River are higher than for most eastern U.S. rivers (*8*). Since the average flow in the Kiskiminetas River is more than 3,000 cubic feet per second (as determined by the Hydrology Section of the Army Corps of Engineers, Federal Building, Pittsburgh, Pa.), the weighted concentration at Apollo represents about 100 millicuries per day. This is 20 times the radioactivity that would be permitted to be released per day from both plants.

Since concentrations of alpha radioactivity range from tenths of a picocurie per liter to more than 100 pCi/liter, the upstream source apparently was fluctuating. Figure 2 shows the monthly average concentration for all three locations. The calculated millicuries per day show that the total radioactivity per day is a function of both the flow rate and concentration but appear to depend more on the flow rate than the concentration.

A 2-day survey by canoe of the Kiskiminetas River watershed was undertaken in May 1966 to determine the cause of the upstream radioactivity. The survey was repeated in June 1967 and additional surveys of the west branch of the Susquehanna River were done in August and November of 1967.

The Kiskiminetas River watershed contains a number of coal mines, whose drainage creates a high acid content (pH = 2-5) in the Kiskiminetas River. Geological publications have described the association of uranium and coal in western Pennsylvania (*1–3*). Since coal mine drainage might be the source of upstream radioactivity, water from several mines was sampled.

Figure 3 shows the detail of the 1966 survey. River samples were taken from the Allegheny to the Loyalhanna reservoir. All large sidestreams were sampled and samples were obtained directly from two mines and a boney pile. The term "boney pile" refers to the shale overcover removed from coal. Most of the river samples were obtained from canoes or flat-bottomed fishing boats, since the Kiskiminetas River has a shallow draft from late spring to fall.

One-liter samples were collected at each location. The acidity of each sample was tested with wide range pH test strips or field pH meters. Most mines and sidestreams showed high acidity. The Kiskiminetas River is one of the more acid rivers in Pennsylvania.

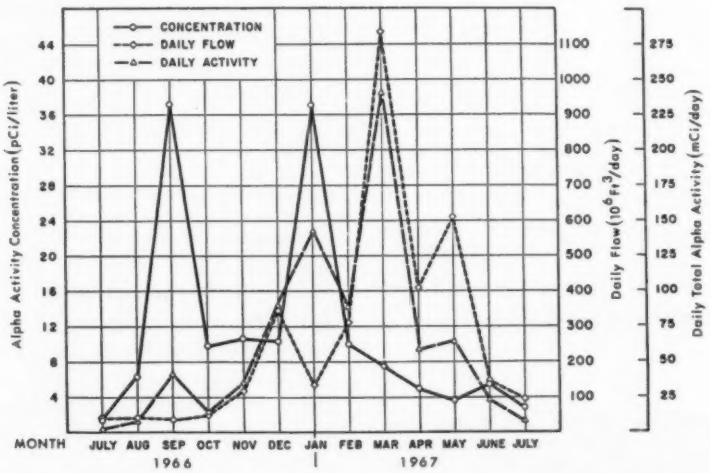

Figure 2. Alpha radioactivity in the Kiskiminetas river, July 1966–July 1967

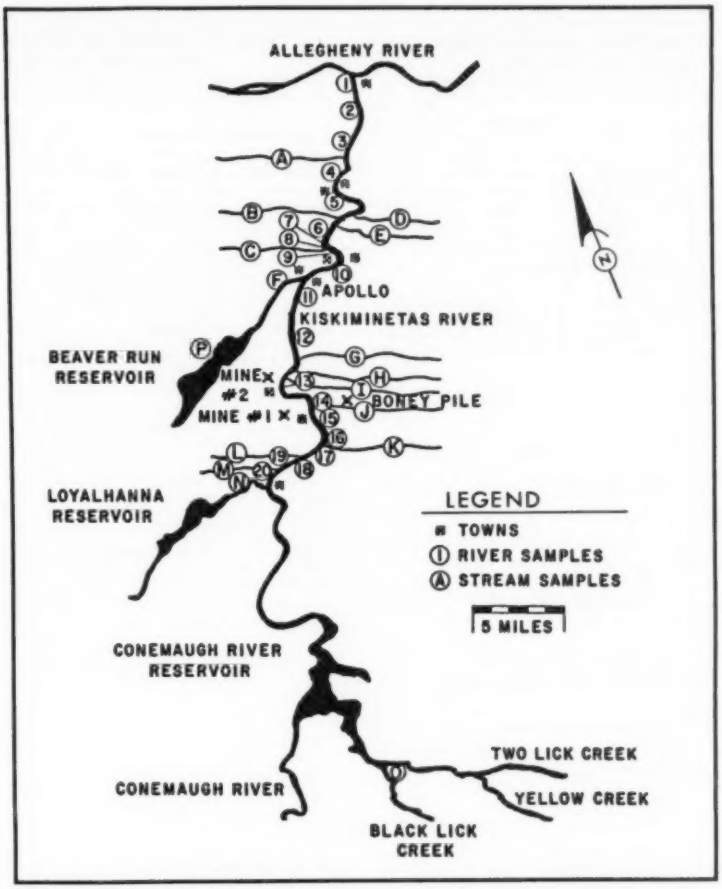

Figure 3. Radioactivity survey on the Kiskiminetas river

The samples were analyzed for gross alpha radioactivity following the general procedures used by the Public Health Service (*4*). The suspended matter was removed by centrifugation and filtration. The filtered water samples were treated with 1 N HNO_3 to digest organic matter evaporated to low volume and transferred to stainless-steel planchets for counting. The planchets were flamed to dull red, cooled and weighed. Alpha-particle counting was done in an alpha scintillation counter whose background never exceeded one count per minute or a gas proportional counter whose background never exceeded 0.3 count per minute. All samples were counted for at least 10 minutes. Correction was made for self-absorption for samples exceeding 10 mg/cm^2.

Suspended solids in the samples were also analyzed for alpha radioactivity. While self-absorption uncertainties were present, most of the radioactivity appeared in the dissolved solids.

Results

The results of the May 1966 survey of the Kismiminetas River watershed are given in table 2. The levels of radioactivity concentrations in coal mine drainage are appreciable considering that the MPC_w for unidentified radionuclides is 10 pCi/liter. Radiochemical analyses were done on several samples. Alpha-particle emitters were determined by alpha spectroscopy except that radium–226 was determined by the radon emanation technique. The radioactivity was found to be predominantly

Table 2. Kiskiminetas River watershed alpha radioactivity survey, May 1966

Sampling point*	Concentration (pCi/liter)	Remarks
River: 1	2.7	Allegheny River
2	18.9	
3	26.9	
4	45.2	
5	25.5	
6	28.2	
7	142.7	Old mine drainage
8	16.8	
9	33.6	
10	17.3	
11	46.4	Downstream of principal mine drainage
12	119.1	Downstream of principal mine drainage
13	81.8	Downstream of principal mine drainage
14	11.8	
15	3.6	
16	14.5	
17	16.4	
18	17.3	
19	12.7	
20	1.8	Upstream of all mines
Stream: A	32.7	Mine drainage
B	30.5	Mine drainage
C	21.6	
D	29.3	
E	20.5	
F	12.7	
G	1.0	
H	2.9	
I	1.0	
J	163.6	Downstream of boney pile
K	1.0	
L	10.0	
M	15.5	
N	4.5	Upstream of all mines
O	3.4	Upstream of all mines
P	17.3	Reservoir, some mine drainage
Mine # 1	174.1	
Mine # 2	120.0	
Boney pile	180.0	Shale overcover of coal

* See figure 3 for sampling point location.

Table 3. Kiskiminetas River watershed, alpha radioactivity survey, June 1967

Sample location	Concentration (pCi/liter)
Conemaugh reservoir	9.1
Mine stream, 1 mile below dam	24.5
Side stream, 2 miles below dam	15.4
Side stream, 3 miles below dam	10.0
Side stream at Deep Rapids	20.0
River, Saltsburg	16.4
Mine stream, Saltsburg	31.8
Fresh stream, 1 mile below Saltsburg	0.9
Side stream, 1.5 miles below Saltsburg	8.2
Mine stream, 2 miles below Saltsburg	24.5
Mine drainage, 2 miles below Saltsburg	14.5
Mine stream, Salina	32.7
Mine drainage, Brownstown	7.3
Mine drainage, 1 mile below Brownstown	19.1
Mine drainage, 1.5 miles below Brownstown	27.3
Beaver Run, W. Apollo	9.1
Mine stream, N. Apollo	41.8
Pine Run Creek	6.4
Side stream, River Road	8.2
Mine drainage, N. Vandergrift	12.7
Stitt's Run	11.8
Storm culvert #1	3.2
Storm culvert #2	3.6
Hungry Hollow Creek	18.2
Fresh water spring, Leechburg	ND
Mine stream, Leechburg	60.0
Mine stream, Baghdad #1	21.8
Mine stream, Baghdad #2	53.6
Strip mine, 2 miles above Allegheny River	32.7
Strip mine stream	30.9
Side stream Kiski Junction	11.8

ND, nondetectable.

uranium–234 and uranium–238; less than 10 percent was from radium–226.

The increased levels of radioactivity appear to be only associated with coal mine drainage. River samples 1 and 20, and stream samples G, H, I, K, N, and O are all upstream from mine drainage and all are low in gross alpha radioactivity.

The Kiskiminetas River watershed survey was repeated in June 1967. The results are given in table 3. Only sidestream samples were taken on this survey to gain additional detail over the 1966 survey. While not as dramatic as the 1966 data, the 1967 data confirmed the high concentrations in coal mine drainage.

A review of the Pennsylvania geological literature indicates that other watersheds might contain radioactivity from mine drainage. Consequently, the west branch of the Susquehanna River was surveyed in August and November 1967. Results of this survey are in table 4. It is immediately apparent that the Susquehanna watershed is much less radioactive. However, this may be misleading since many of the samples were collected following heavy rains. In any case, the higher radioactivity in some of the coal mine drainage is evident.

Table 4. West Branch, Susquehanna River watershed alpha radioactivity survey, August and November 1967

Sample location	Concentrations (pCi/liter)
Mine drainage, W. Decatur	ND
Moshannon Creek, Phillipsburg	1.66
Moshannon Creek, Route 153	0.77
Lick Run, Shawsville	.11
Deep Mine drainage, Osceola Mills	14.55
Susquehanna River, Clearfield (above mine pollution)	ND
Susquehanna River, above Shawsville power station	ND
Susquehanna River, below Shawsville	.31
Trout Run, Mine stream	.31
Mine Settling Ponds, Karthaus	2.47
Mosquito Creek, unpolluted	ND
Deer Creek, unpolluted	ND
Shintown Run, Mine Stream	ND
Kettle Creek, Mine Stream	.33
Cooks Run, Mine Stream	2.66
Strip Mine, Chilcote farm	8.06
Indian Caverns	ND

ND, nondetectable

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SECTION I. MILK AND FOOD

Milk Surveillance[1]

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long term concentration trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network, sponsored by the National Center for Radiological Health and the National Center for Urban and Industrial Health, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments have also initiated local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports.* Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and the U.S. Public Health Service)—5 sampling stations,

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Detailed sampling locations provided for by the State networks are presented in another section of this report.

Based on the similar purpose for these sampling activities, a format has been developed to integrate the complementary data that are routinely obtained by these several milk networks. To do this, it was necessary (1) to determine whether the data being generated by the various laboratories were accurate and satisfactorily comparable and (2) to develop a common reporting basis. A discussion of existing radiation protection guidance applicable in the United States is also included, in order to place the significance of the U.S. data reported in perspective.

[1] Special report prepared by Marvin Rosenstein, senior technical editor, Radiological Health Data and Reports, with the assistance of Warren A. Brill, technical editor, Radiological Health Data and Reports, and Mary H. Nesdore, public health analyst, Radiation Exposure Intelligence Section, Standards and Intelligence Branch, National Center for Radiological Health.

Figure 1. Milk sampling networks in the western Hemisphere reported in *Radiological Health Data and Reports*

Radionuclide and element coverage

Experience has established that relatively few of the many radionuclides occurring or formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium–89, strontium–90, iodine–131, cesium–137, and barium–140. A sixth radionuclide, potassium–40, occurs naturally in 0.0118 percent abundance of the element potassium (*15*) resulting in a specific activity for potassium–40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both these elements in milk have been measured extensively and are relatively constant. A brief review of findings over a 3-year period is presented.

A study was made of the PHS Pasteurized Milk Network (PMN) results for calcium content in milk for the period May 1963–March 1966 (*2*). The overall variability of these results was determined, taking into consideration such factors as analytical reproducibility, laboratory bias, sampling, seasonal effects, and geographical differences. The outcome of that analysis was the development of an average value for the PMN and its 2-standard deviation variation, 1.16 ± 0.08 g/liter (~ 7 percent), as an appropriate calcium content in milk for use in general radiological health calculations or discussions. As a result of a parallel study, an average value for the PMN, 1.51 ± 0.21 g/liter (~ 14 percent), for potassium content in milk was developed (*3*).

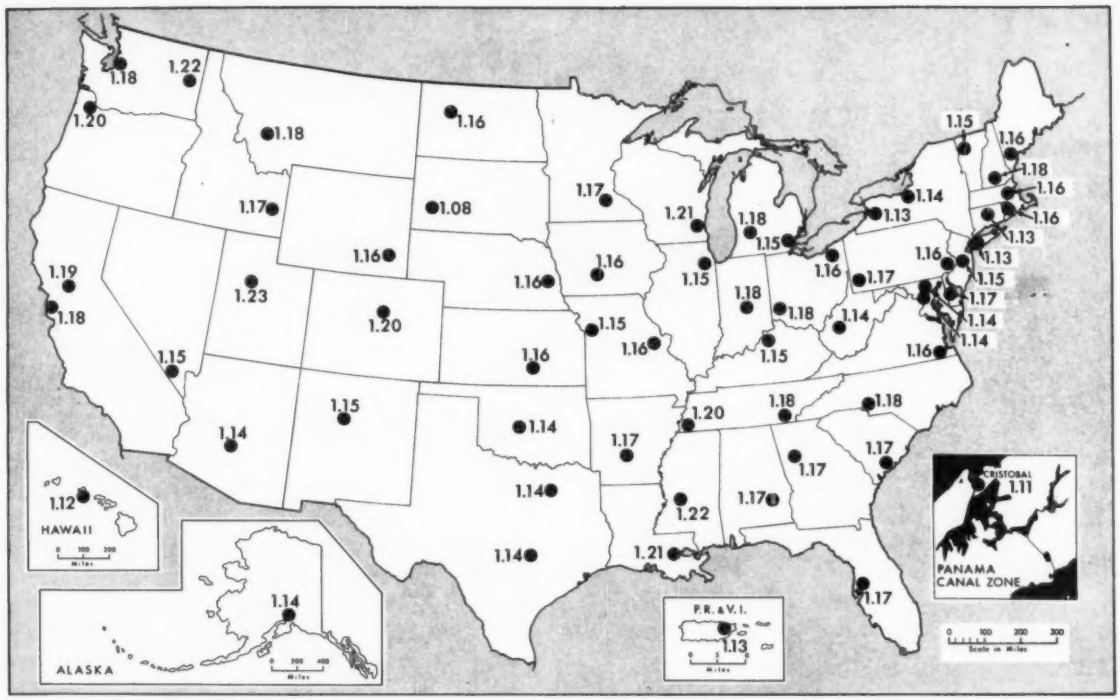

Figure 2. Average calcium content (g/liter) in pasteurized milk at PMN stations

The content of calcium in milk observed at each of the 63 PMN sampling stations is given in figure 2. The 2–standard deviation value given above for the grand mean of the 63 station averages includes not only the variation among the station averages (4.6 percent), but also includes the average variation observed at a single sampling location from all normal causes (5.5 percent) [2]. The average calcium value for the network and the range of values in figure 2 (1.08 to 1.23 g/liter) are in good agreement with average calcium values and ranges given in dairy references (*4, 5*). A similar presentation for potassium is given in figure 3. The range of potassium content in milk for the PMN stations is 1.45 to 1.66 g/liter. The variation among the 63 station averages was 5.5 percent and the average variation observed at a single sampling location was 13.7 percent [3].

[2] These two variations are combined as $[(4.6)^2 + (5.5)^2]^{1/2}$ to yield an overall variation of ~ 7 percent (*2*).

[3] These two variations are combined as in footnote 2 to yield an overall variation of ~ 14 percent.

Extension of these findings for the PMN to the State networks considered in this presentation, particularly extension of the 63 individual station averages in figures 2 and 3, allows the average calcium and potassium content and variation to be stated without continuous monitoring for these elements.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the National Center for Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined in the literature (*6*).

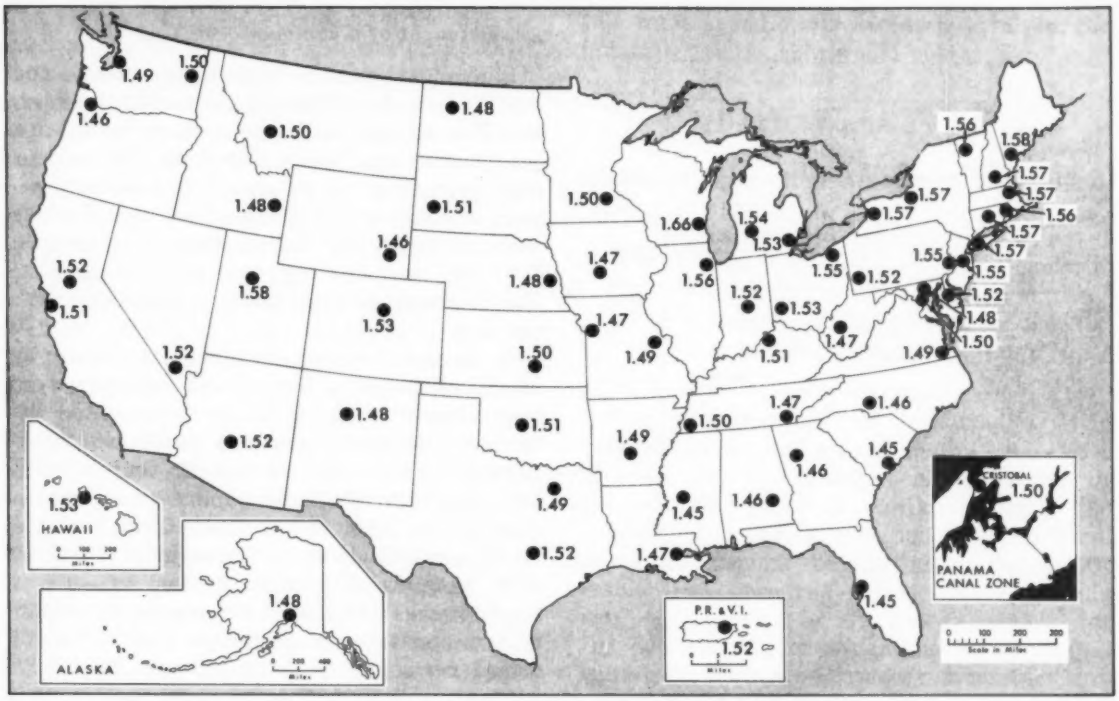

Figure 3. Average potassium content (g/liter) in pasteurized milk at PMN stations

The most recent study was conducted in the spring of 1967, with 40 laboratories participating in an experiment on milk samples containing known concentrations of strontium–90, iodine–131, and cesium–137 (*7*). Of the 19 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 18 participated in the experiment. Discussion of the results of this study is limited to these laboratories. The experiments were conducted at four concentrations of iodine–131, two concentrations of cesium–137, and two concentrations of strontium–90, which represented both high and low levels.

Figures 4 to 6 present the results for the concentrations of strontium–90, iodine–131, and cesium–137 tested which are most representative of current environmental levels.

In figures 4 to 6 a laboratory's results indicated analytical accuracy if the mean value (a measure of bias) and the range value (a measure of internal precision) both fell within the 3–standard deviation limits for the concentration of the particular radionuclide that was measured. Mean and/or range values that fell outside the 3–standard deviation limits reflected analytical errors that should be corrected.

In the majority of cases, the results for the laboratories fell within the 3–standard deviation limits considered appropriate for the various analyses (*7*). Several results were outside the 3–standard deviation limits and the most deviant of these represented biases from the expected values of 20 to 30 percent. The number of laboratories shown in a specific figure for a particular radionuclide analysis does not total 18 because every laboratory reporting in *Radiological Health Data and Reports* does not routinely perform all of the radionuclide analyses considered. These results were for conditions in the spring of 1967, and therefore do not reflect improvements that may have taken place as a result of the findings of the study. Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error because of disagreement among the independently obtained data.

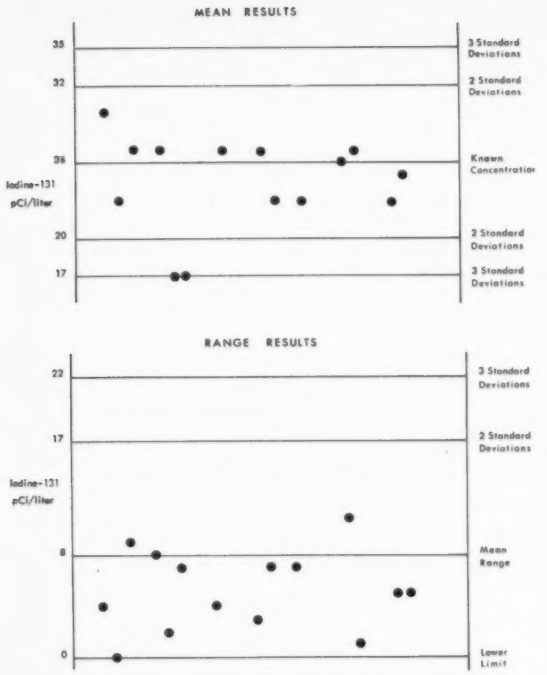

Figure 4. Interlaboratory comparison of iodine–131 measurements in milk at a concentration of 26 pCi/liter

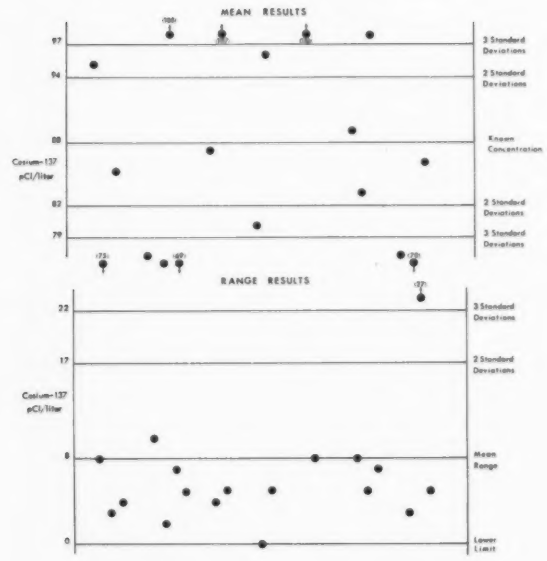

Figure 5. Interlaboratory comparison of cesium–137 measurements in milk at a concentration of 88 pCi/liter

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that regularly report in *Radiological Health Data and Reports* were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion exchange technique and determined by beta-particle counting in low background detectors, and the gamma-ray emitters (potassium–40, iodine–131, cesium–137, and barium–140) are determined by gamma-ray spectroscopy on the whole milk. Each laboratory has its own modifications and refinements of these basic methods. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports.*

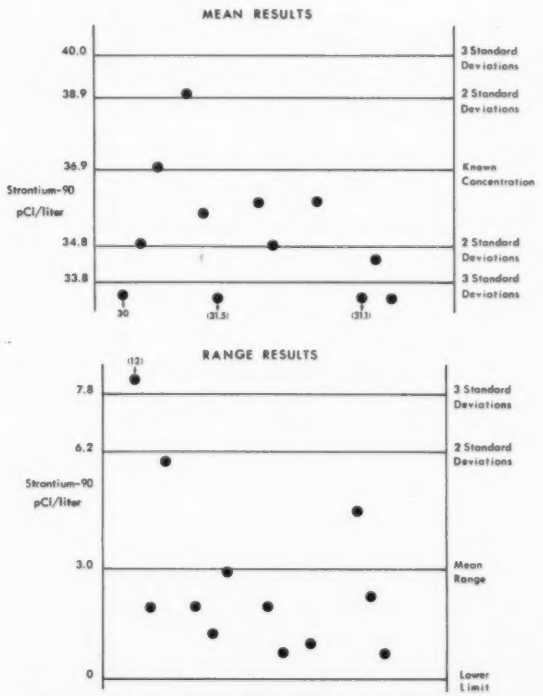

Figure 6. Interlaboratory comparison of strontium–90 measurements in milk at a concentration of 36.9 pCi/liter

A recent article (*8*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis not only varies among the networks, but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions will be reflected in the data presentation. While this may appear to complicate comparisons of data, current levels for strontium–90 and cesium–137 are relatively stable over the time periods involved and sampling frequency is not critical. For the case of the short-lived radionuclides, particularly iodine–131, the frequency of analysis is critical, and is generally increased at the first measurement or recognition of a new influx of the radionuclide.

Also reflected in the data presentation will be whether raw or pasteurized milk was collected. A recent analysis (*9*) of raw and pasteurized milk samples collected during the period, January 1964–June 1966, indicates that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium–90 and cesium–137 in that analysis.

The following definition of minimum detectable activity (MDA) is given in National Bureau of Standards Handbook 86 (*10*): ". . . that activity of a radionuclide concerned, which, in a given counting time, increases the reading of an instrument by an amount equal to three times the standard deviation of the background recorded in that time." If one assumes that only random radioactive decay is involved, the following relationship would hold:

$$\text{MDA (pCi/liter)} = \frac{3s}{f} = \frac{3}{f}\sqrt{\frac{B}{t}}$$

where s = standard deviation of background, cpm
B = background counting rate, cpm
t = counting time for routine analysis, minutes
f = sensitivity of the instrument for the procedure employed, cpm/(pCi/liter).

For measurements of beta radioactivity (strontium–89 and strontium–90) the above formula does not consider the interaction of the sample counting variation with the background counting variation. For measurements of gamma radioactivity (iodine–131, cesium–137, barium–140), the above formula can only be based on the energy interval for the gamma ray for which the instrument is calibrated. Therefore, it does not consider contributions to that energy interval from other gamma rays of the same or other radionuclides that occur in other energy intervals in the composite gamma-ray spectrum. This theoretical approach to developing a minimum level for reporting of milk data, therefore, does not adequately reflect all the conditions that determine an actual capability for laboratory measurements.

A second term, the practical reporting level, will now be introduced. The practical reporting level is based on a laboratory's experience in performing the analytical determinations and is a function of its methodology and instrumentation. Each of the networks reported in *Radiological Health Data and Reports* has developed independently such a practical reporting level, most often based on 2–standard deviation counting errors or 2–standard deviation total analytical errors from replicate analyses experiments. Minimum detectable activities, as calculated, and practical reporting levels, as defined, for each of the various networks are presented in table 1. As expected, the minimum detectable activities are lower than the practical reporting levels. Since the practical reporting level reflects additional factors

Table 1. Minimum detectable activities and practical reporting levels for analyzing laboratories

Sampling network	Strontium-89 (pCi/liter)		Strontium-90 (pCi/liter)		Iodine-131 (pCi/liter)		Cesium-137 (pCi/liter)		Barium-140 (pCi/liter)	
	MDA [a]	PRL [b]	MDA	PRL	MDA	PRL	MDA	PRL	MDA	PRL
California	2	3	1	2	5	7	5	7	5	7
Colorado	(c)	(c)	(c)	(c)	15	25	17	25	16	24
Connecticut	0.3	3	0.3	2	7	10	6	10	7	10
Florida	(c)	(c)	1	2	8	10	9	10	8	10
Indiana	.6	1	.6	1	5	10	5	10	5	10
Iowa	(c)	(c)	.5	2	6	10	5	10	(d)	(d)
Michigan	(c)	(c)	1	2	2	14	5	10	2	10
Minnesota	(c)	(c)	.4	1	4	4	4	4	(c)	(c)
New York	2	3	3	3	4	5	12	20	25	100
Oklahoma	(c)	(c)	(c)	(c)	2	3	6	10	(c)	(c)
Oregon	(c)	(c)	2	2	10	15	10	15	10	15
Pennsylvania	(c)	(c)	.9	1	8	10	7	10	18	20
Tennessee	2	5	2	2	8	10	8	10	8	10
Texas	(c)	(c)	.6	2	3	10	3	10	3	5
Washington	(c)	(c)	.3	1	8	10	8	15	8	15
Canada	.3	5	.4	3	3	5	5	10	(c)	(c)
Pasteurized Milk Network	NA	5	NA	2	NA	10	NA	10	NA	10
NERHL [e]	1	NA	1	NA	7	NA	7	NA	7	NA
SERHL [e]	(c)	NA	(c)	NA	(c)	NA	(c)	NA	(c)	NA
SWRHL [e]	1	NA	1	NA	10	NA	10	NA	5	NA
Pan American Health Organization (SERHL)	(c)	5	(c)	2	(c)	10	(c)	10	(c)	10

[a] Minimum detectable activity as calculated by the method described in the text.
[b] Practical reporting level as provided by network.
[c] Analysis not routinely performed by network.
[d] Northeastern Radiological Health Laboratory, Southeastern Radiological Health Laboratory, and Southwestern Radiological Health Laboratory, respectively.
[e] No estimate available.
NA, not applicable.

that are not considered by the minimum detectable activity calculation, such as sample preparation, counting errors not inherent in the minimum detectable activity, and chemical yield variations, it will be used as a more practical basis for reporting data.

In developing a single presentation for the data from the various networks, it would be confusing and impractical to continually refer to a compilation such as table 1 for the various practical reporting levels each time the data are presented. Review of table 1 indicates that while the practical reporting levels vary, the majority of these for any specific radionuclide is within a relatively narrow range. Considering also that these levels are not derived in a consistent manner for all the networks, it would be prudent to simplify this procedure and select an appropriate value for each radionuclide that reflects a meaningful measurement. The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium–89	5
Strontium–90	2
Iodine–131	10
Cesium–137	10
Barium–140	10

However, those networks whose practical reporting levels were given as greater than those above will use their reported values in order that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, will be discussed in relation to the revised data presentation format.

Analytical errors of precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks. The precision errors given in table 2

Table 2. Two-standard deviation errors for analytical methodology [a]

Sampling network	Strontium-89		Strontium-90		Iodine-131		Cesium-137		Barium-140	
	Lower levels	Higher levels	Lower levels	Higher levels	Lower levels	Higher levels	Lower levels	Higher levels	Lower levels	Higher levels
California (A)	±3 (<30)	±10% (≥30)	±2 (<20)	±10% (≥20)	±7 (<100)	±10% (≥100)	±7 (<100)	±10% (≥100)	±7 (<100)	±10% (≥100)
Colorado (A)	[b]	[b]	[b]	[b]	±25 (<100)	±10% (≥100)	±25 (<100)	±10% (≥100)	±25 (<100)	±10% (≥100)
Connecticut (C)	[c]	±1 (>20)	[c]	±1 (>20)	[c]	±8 (>100)	[c]	±7 (>100)	[c]	±8 (>100)
Florida (C)	[b]	[b]	±2 (20)	±5% (100)	±10 (100)	2% (1000)	±10 (100)	2% (1000)	±10 (100)	2% (1000)
Indiana (C)	±1 (<20)	±6% (≥20)	±1 (<20)	±6% (≥20)	±5 (<100)	±6% (≥100)	±5 (<100)	±6% (≥100)	±5 (<100)	±6% (≥100)
Iowa (C)	[b]	[b]	±2 (<20)	±10% (≥20)	±6 (<100)	±6% (≥100)	±6 (<100)	±6% (≥100)	[b]	[b]
Michigan (C)	[b]	[b]	±1 (<20)	[c]	±5 (<50)	[c]	±6 (<50)	[c]	±5 (<50)	
Minnesota (C)	[b]	[b]	±1 (<20)	±8% (≥20)	±4 (<50)	±8% (≥50)	±4 (<50)	±8% (≥50)	[b]	[b]
New York (C)	[c]	±10% (≥15)	[c]	±10% (≥30)	[c]	±10% (≥20)	[c]	±10% (≥100)	[c]	±10% (≥250)
Oklahoma (C)	[b]	[b]	[b]	[b]	±2 (<20)	±10% (≥20)	±4 (<55)	±10% (≥55)	[b]	[b]
Oregon (C)	[b]	[b]	±2 (<20)	±10% (≥20)	±10 (<100)	±10% (≥100)	±10 (<100)	10% (≥100)	±10 (<100)	±10% (≥100)
Pennsylvania (C)	[b]	[b]	±2 (<20)	[c]	±10 (20)	[c]	±10 (100)	[c]	±10 (<20)	[c]
Tennessee (C)	±3 (<50)	[c]	±2 (<50)	[c]	±9 (80)	±35 (@700)	±4 (50)	±18 (400)	±12 (75)	±4 (600)
Texas (C)	±5 (<50)	±10% (≥50)	±2 (<20)	±10% (≥20)	±10 (<100)	±10% (>100)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)
Washington (C)	[c]	[b]	±0.4–1 (1–10)	±1–3 (10–100)	±7 (<100)	±7–9 (100–300)	±7–9 (15–100)	±9–12 (100–300)	±8 (<100)	±8–12 (100–400)
Canada [^{131}I and ^{137}Cs(C) ^{89}Sr and ^{90}Sr(A)]	±5 (<50)	±10% (≥50)	±3 (<50)	±6% (≥50)	±15% (<50)	±10% (≥50)	±4 (<100)	±4% (≥100)	[b]	[b]
Pasteurized Milk Network, NERHL, SERHL, SWRHL [d] (A)	±5 (<50)	±10% (≥50)	±2 (<20)	±10% (≥20)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)
Pan American Health Organization, SERHL (A)	±5 (<50)	±10% (≥50)	±2 (<20)	±10% (≥20)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)	±10 (<100)	±10% (≥100)

[a] All values are in units of pCi/liter, except as indicated as percent (%). The values in parentheses indicate concentration levels in pCi/liter.
(A)—Total analytical error.
(C)—Counting error only.
[b] Analysis not routinely performed by network.
[c] No estimate available.
[d] Northeastern Radiological Health Laboratory, Southeastern Radiological Health Laboratory, Southwestern Radiological Health Laboratory, respectively.

are either the 2-standard deviation counting error or 2-standard deviation total analytical error. Review of table 2 indicates that precision errors for each of the radionuclides would fall in the following ranges.

Radionuclide	Analytical errors of precision, 2-standard deviation
Strontium–89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium–90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine–131	4–10 pCi/liter for levels <100 pCi/liter; 6–10% for levels ≥100 pCi/liter
Cesium–137	4–10 pCi/liter for levels <100 pCi/liter; 4–10% at levels ≥100 pCi/liter
Barium–140	5–10 pCi/liter at levels <100 pCi/liter; 6–10% for levels ≥100 pCi/liter

For iodine–131, cesium–137 and barium–140 there is one exception to these general ranges which is the 25 pCi/liter value at levels <100 pCi/liter for Colorado. The larger Colorado variation at low levels is a result of the counting time and sample volume presently considered practical by Colorado for evaluation of its milk supplies. This is also reflected in the practical reporting level for that network.

While these errors reflect the precision of the routine measurements, accuracy of the analytical results is best monitored through interlaboratory quality control procedures, such as the one discussed earlier.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance for the use of Federal agencies in the formulation of radiation standards.

Radiation Protection Guides

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risks to the general public that might result from exposures from routine uses of ionizing radiation and the benefits obtained from the activities causing the exposure.

FRC Reports 1 and 2 (*11, 12*) set forth RPG's for specific critical organs (thyroid, bone, bone marrow, and whole body) and intake guidance for strontium–89, strontium–90 and iodine–131. At the same time, the FRC recommended that for radionuclides not specifically considered in the report, Federal agencies should use concentration values which are consistent with recommended RPG's and the general guidance on intake. Therefore, using appropriate FRC recommendations, intake guidance for cesium–137 has been considered also and included in this summary.

The basic guide used for cesium–137 is 0.5 rad/yr[4] as recommended by the FRC for the annual whole body dose to the individual in the population or 0.17 rad/yr for a suitable sample of the exposed population group. Using the dose relationship for cesium–137 given in FRC Report 7 (*14*) and assuming an equilibrium condition for uptake and excretion of cesium–137 in the body, one obtains the equation:

$$D = (11)\frac{I}{W}1.44T_B$$

where, D = the dose in $\frac{\text{rads}}{\text{year}}$

I = the intake in $\frac{\mu\text{Ci}}{\text{day}}$ of cesium-137

[4] 0.5 rem/yr is given in FRC Report No. 1 (*11*) for whole body dose. In the case of cesium–137, the rem and the rad can be taken as equivalent units.

W = the body weight in kilograms
11 = dose conversion factor based on the absorption of 0.59 MeV per disintegration
1.44 T_B = the mean biological life in days
where, T_B = the biological half life in days.

Where milk is the vector of interest, the infant is the critical individual in the population. The continuous daily intake corresponding to a whole body dose of 0.17 rad/yr is calculated to be 3,600 pCi/day, assuming the infant weighs 10 kg and the biological half life of cesium–137 is 30 days (*14*).

For the purpose of evaluating population exposure, the daily intake of radionuclides by exposed population groups averaged over a year constitutes an appropriate criterion. However, in order to provide guidance to Federal agencies in developing appropriate control programs, the FRC described a graded approach involving three ranges of transient rates of daily intake as determined by surveillance, applicable to different degrees of action as follows:

Range I —periodic confirmatory surveillance as necessary;
Range II —quantitative surveillance and routine control;
Range III—evaluation and application of additional control measures as necessary.

Based on the above considerations, table 3 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable.

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1 liter per day intake of milk (*13*, *14*) one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Protective Action Guides

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a 1 or 2-year

Table 3. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/yr)	Guidance for suitable samples of exposed population group [a]				
			RPG (rad/yr)	Corresponding continuous daily intake (pCi/day)	Range I (pCi/day)[b]	Range II (pCi/day)[b]	Range III (pCi/day)[b]
Strontium-89	Bone	[c] 1.5	0.5	[d] 2,000	0–200	200–2,000	2,000–20,000
	Bone marrow	[c] 0.5	0.17				
Strontium-90	Bone	[c] 1.5	0.5	[d] 200	0–20	20–200	200–2,000
	Bone marrow	[c] 0.5	0.17				
Iodine-131	Thyroid	1.5	0.5	100	0–10	10–100	100–1,000
Cesium-137 [e]	Whole body	0.5	0.17	3,600	0–360	360–3,600	3,600–36,000

[a] Suitable samples which represent the limiting conditions for this guidance are:
Strontium-89, -90—general population;
Iodine-131—children, 1 year of age;
Cesium-137—infants.
[b] Based on an average intake of 1 liter of milk per day.
[c] A dose of 1.5 rad/yr to the bone is estimated to result in a dose of 0.5 rad/yr to the bone marrow.
[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.
[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

FRC Reports 5 and 7 (*13*, *14*) set forth PAG's for the thyroid, bone marrow, and whole body doses from ingestion of foods contaminated with radionuclides following an acute contaminating event. For the case of strontium–89, strontium–90, and cesium–137 contamination, the Council defined three categories of dietary pathways in which action may be required following an acute event as follows:

Category I —transmission of radionuclides to man through the pasture-cow-milk pathway;

Category II —transmission of radionuclides to man through dietary pathways other than the pasture-cow-milk pathway during the first year following an acute contaminating event;

Category III—long-term transmission of strontium–90 and cesium–137 through soil into plants in the years following a contaminating event.

This discussion is restricted to a consideration of Category I.

In the case of iodine–131 contamination, the maximum concentration of iodine–131 observed in milk which may occur 2 to 4 days following an acute incident, can be used to project doses for comparison to the PAG for the thyroid. For strontium–89, strontium–90 and cesium–137, the total dose to the critical organ resulting from contributions of all three of these radionuclides must be considered to determine whether the projected dose will exceed the recommended PAG for the organ of interest (bone marrow or whole body).

Based on the above conditions, table 4 represents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. Also given in table 4 are milk concentrations for each of the radionuclides considered, in the absence of the others, which if attained after an acute incident would result in doses equivalent to the appropriate

Table 4. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclides	Critical organ	PAG for individuals in general population (rads)	Category I (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Concentration at maximum in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15 [a, b]	3 in first yr; total dose not to exceed 5 [a, b]	[c] 1,110,000
Strontium-90	Bone marrow			[c] 51,000
Cesium-137	Whole body			[c] 720,000
Iodine-131	Thyroid	30	10	[d] 70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.
[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.
[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.
[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered.

PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for an acute deposition and the pasture-cow-milk-man pathway and from an estimate of the intake prior to reaching the maximum concentration (*13*). Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples.

Data reporting format

Commencing with the present issue of *Radiological Health Data and Reports*, milk surveillance data are presented in a revised format integrating the various milk surveillance networks. Repetitive descriptions of the individual network activities and long-term milk concentration trends will be discontinued, however, the factors necessary for interpreting current data will be appropriately summarized.

Table 5 presents this revised format. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationships between the PMN

Table 5. Concentrations of radionuclides in milk for August 1968 and 12-month period September 1967 through August 1968

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
United States:								
Ala:	Montgomery[c]	P	10	9	0 (5)	0	16 (5)	14
Alaska:	Palmer[c]	P	NA	5	0 (3)	0	22 (3)	14
Ariz:	Phoenix[c]	P	NA	1	0 (5)	0	8 (5)	2
Ark:	Little Rock[c]	P	24	21	0 (4)	0	18 (4)	19
Calif:	Sacramento[c]	P	0	2	0 (5)	0	3 (5)	6
	San Francisco[c]	P	0	1	0 (5)	0	0 (5)	5
	Del Norte	P	23	18	0	0	34	21
	Fresno	P	0	0	0	0	22	5
	Humboldt	P	4	4	0	0	23	10
	Los Angeles	P	0	0	0	0	17	5
	Mendocino	P	3	2	0	0	19	4
	Sacramento	P	3	2	0	0	16	5
	San Diego	P	0	0	0	0	20	2
	Santa Clara	P	0	4	0	0	14	6
	Shasta	P	4	3	0	0	0	2
	Sonoma	P	3	2	0	0	21	6
Colo:	Denver[c]	P	4	4	0 (5)	0	12 (5)	7
	Western	R	—	—	(•)	(•)	(•)	(•)
	Northeast	R	—	—	•(3)	(•)	(•)	(•)
	Eastern	R	—	—	NS	(•)	NS	(•)
	Southeast	R	—	—	NS	(•)	NS	(•)
	South Central	R	—	—	NS	(•)	NS	(•)
Conn:	Hartford[c]	P	13	10	0 (5)	0	16 (5)	12
	Central	R	9	8	0 (5)	0	13 (5)	9
Del:	Wilmington[c]	P	10	11	0 (5)	0	8 (5)	8
D.C.:	Washington[c]	P	9	10	0 (5)	0	10 (5)	7
Fla:	Tampa[c]	P	9	8	0 (4)	0	71 (4)	66
	West	R	9	17	14	3	28	25
	North	R	NS	17	NS	3	NS	26
	Northeast	R	9	9	0	2	124	91
	Central	R	7	10	0	8	81	108
	Tampa Bay area	R	7	8	0	0	77	76
	Southeast	R	8	9	0	2	111	95
Ga:	Atlanta	P	19	15	0 (4)	0	21 (4)	20
Hawaii:	Honolulu[c]	P	5	3	0 (4)	1	0 (4)	4
Idaho:	Idaho Falls[c]	P	8	6	0 (4)	0	8 (4)	8
Ill:	Chicago[c]	P	10	9	0 (4)	0	11 (4)	10
Ind:	Indianapolis[c]	P	8	7	0 (4)	0	3 (4)	7
	Northeast	P	12	9	0	0	0	5
	Southeast	P	14	10	0	0	0	10
	Central	P	7	8	0 (4)	0	0 (4)	6
	Southwest	P	9	10	0	2	15	12
	Northwest	P	10	9	0 (4)	0	15 (4)	8
Iowa:	Des Moines[c]	P	4	7	0 (4)	0	13 (4)	7
	Iowa City	P	8 (3)	7	0 (3)	0	15 (4)	2
	Des Moines	P	5 (2)	7	0 (2)	0	9 (2)	2
	Spencer	P	8	7	0	0	0	8
	Charles City	P	NS		NS		NS	
Kans:	Wichita[c]	P	4	9	0 (4)	0	1 (4)	5
Ky:	Louisville[c]	P	14	12	0 (4)	0	1 (4)	5
La:	New Orleans[c]	P	18	21	0 (5)	0	25 (5)	24
Maine:	Portland[c]	P	14	12	0 (4)	0	32 (4)	29
Md:	Baltimore[c]	P	13	10	0 (4)	0	13 (4)	6
Mass:	Boston[c]	P	16	13	0 (4)	0	30 (4)	25
Mich:	Detroit[c]	P	9	9	0 (4)	0	9 (4)	11
	Grand Rapids[c]	P	11	10	0 (4)	0	13 (4)	14
	Bay City	P	4	4	•(2)	(•)	7 (2)	5
	Charlevoix	P	NS	5	NS	(•)	NS	6
	Detroit	P	5	5	•(4)	(•)	3 (4)	5
	Grand Rapids	P	NA	5	•(4)	(•)	12 (4)	7
	Lansing	P	5	4	•(2)	(•)	0 (2)	2
	Marquette	P	9	7	•(2)	(•)	32 (2)	21
	Monroe	P	0	4	•(2)	(•)	0 (2)	2
Minn:	Minneapolis[c]	P	14	11	0 (4)	0	11 (4)	12
	Bemidji	P	20	15	0	0	38	22
	Mankato	P	5	6	0	0	0	0
	Rochester	P	10	8	0	0	12	0
	Duluth	P	25	19	0	0	33	28
	Worthington	P	5	6	0	0	0	0
	Minneapolis	P	14	12	0	0	17	12
	Fergus Falls	P	12	9	0	0	10	11
	Little Falls	P	10	9	0	0	19	13
Miss:	Jackson[c]	P	13	17	0 (4)	0	16 (4)	15
Mo:	Kansas[c]	P	10	8	0 (5)	0	9 (5)	5
	St. Louis[c]	P	7	9	0 (5)	0	8 (5)	8
Mont:	Helena	P	6	5	0 (4)	0	10 (4)	8
Nebr:	Omaha[c]	P	6	7	0 (5)	0	10 (5)	5
Nev:	Las Vegas[c]	P	0	1	0 (4)	0	1 (4)	4
N.H.:	Manchester[c]	P	18	14	0 (4)	0	55 (4)	36
N.J.:	Trenton[c]	P	11	10	0 (4)	0	10 (4)	10
N.Mex:	Albuquerque[c]	P	4	2	0 (4)	0	0 (4)	2

See footnotes at end of table.

Table 5. Concentrations of radionuclides in milk for August 1968 and 12-month period September 1967 through August 1968—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
N.Y.:	Buffalo[c]	P	9 (5)	9	0 (5)	0	10 (5)	14
	New York City[c]	P	14	10	0 (4)	0	15 (4)	13
	Syracuse[c]	P	8	7	0 (4)	0	6 (4)	7
	Albany	P	10 (5)	8	0 (4)	1	[c] (2)	12
	Buffalo	P	8	4	0	2	([c])	14
	Massena	P	12	10	0	1	([c])	22
	Newburg	P	([c])	9	0	15	([c])	1
	New York City	P	11 (2)	10	0 (2)	1	29 (2)	23
	Syracuse	P	NS	10	NS	2	NS	15
N.C.:	Charlotte[c]	P	16	15	0 (4)	1	15 (4)	12
N. Dak:	Minot[c]	P	11	11	0 (4)	0	15 (4)	12
Ohio:	Cincinnati[c]	P	8	9	3 (4)	0	7 (4)	7
	Cleveland[c]	P	13	10	0 (5)	0	6 (5)	8
Okla:	Oklahoma City[c]	P	10	10	0 (4)	0	1 (4)	4
	Oklahoma City	P	NS	NS	NS	NS	NS	NS
	Enid	P	NS	NS	NS	NS	NS	NS
	Tulsa	P	NS	NS	NS	NS	NS	NS
	Lawton	P	NS	NS	NS	NS	NS	NS
	Ardmore	P	NS	NS	NS	NS	NS	NS
Ore:	Portland[c]	P	6	7	0 (5)	0	13 (5)	15
	Baker	P	NA	6	([d])	([d])	([d])	4
	Coos Bay	P	NA	12	([d])	([d])	([d])	15
	Eugene	P	NA	4	([d])	([d])	35	12
	Medford	P	NA	4	([d])	([d])	([d])	9
Ore:	Portland composite	P	NA	8	([d])	([d])	19 (5)	11
	Portland local	P	NA	7	([d])	([d])	16 (5)	14
	Redmond	P	NA	5	([d])	([d])	([d])	9
	Tillamook	R	NA	10	([d])	([d])	30	27
Pa:	Philadelphia[c]	P	12	9	0 (5)	0	7 (5)	9
	Pittsburgh[c]	P	12	12	0 (4)	0	11 (4)	14
	Dauphin	P	13	8	0	0	30	15
	Erie	P	10 (2)	12	0	0	47	22
	Philadelphia	P	11	10	0	0	27	16
	Pittsburgh	P	17	13	0	0	13	15
R.I.:	Providence[c]	P	13	11	0 (4)	0	27 (4)	18
S.C.:	Charleston[c]	P	16	15	0 (4)	0	29 (4)	27
S. Dak:	Rapid City[c]	P	11	10	0 (4)	0	9 (4)	10
Tenn:	Chattanooga[c]	P	13	14	0 (4)	0	14 (4)	13
	Memphis[c]	P	12	12	0 (5)	0	3 (5)	5
	Chattanooga	P	12	14	0 (4)	0	12 (4)	18
	Clinton	P	14	14	0 (2)	4	16 (2)	22
	Knoxville	P	12	13	13	3	0	24
	Nashville[d]	P	NS	8	NS	0	NS	20
Tex:	Austin[c]	P	3	4	0 (3)	0	0 (3)	2
	Dallas[c]	P	7	7	0 (4)	0	3 (4)	6
	Amarillo	R	NA	5	NA	0	NA	0
	Corpus Christi	R	NA	4	NA	0	NA	0
	El Paso	R	NA	2	NA	0	NA	0
	Fort Worth	R	NA	6	NA	0	NA	0
	Harlington	R	NA	3	NA	0	NA	0
	Houston	R	NA	11	NA	0	NA	8
	Lubbock	R	NA	4	NA	0	NA	0
	Midland	R	NA	4	NA	0	NA	0
	San Antonio	R	NA	3	NA	0	NA	0
	Texarkana	R	NA	11	NA	0	NA	8
	Uvalde	R	NA	2	NA	0	NA	0
	Wichita Falls	R	NA	10	NA	0	NA	0
Utah:	Salt Lake City[c]	P	4	5	0 (4)	0	8 (4)	11
Vt:	Burlington[c]	P	11	11	0 (4)	0	6 (4)	11
Va:	Norfolk[c]	P	14	11	0 (5)	0	6 (5)	8
Wash:	Seattle[c]	P	12	9	0 (5)	0	26 (5)	21
	Spokane[c]	P	5	7	0 (4)	0	4 (4)	11
	Benton County	R	NS	0	NS	0	NS	([d])
	Deer Park	R	4	4	0	0	([d])	([d])
	Elma	R	4	5	0	0	26	23
	Franklin County	R	0	0	0	0	([d])	([d])
	Moses Lake	R	0	0	0	0	([d])	([d])
	Pierce County	R	5	3	0	0	29	7
	Sandpoint, Idaho	R	7	7	0	0	29	23
	Skagit County	R	7	4	0	0	([d])	15
W. Va:	Charleston[c]	P	12	12	0 (2)	0	8 (2)	4
Wisc:	Milwaukee[c]	P	8 (4)	8	0 (4)	0	8 (4)	11
Wyo:	Laramie[c]	P	4	4	0 (4)	0	3 (4)	7
Canada:								
Alberta:	Calgary	R	10	9	—	—	20	18
	Edmonton	R	7	8	—	—	22	22
British Columbia:	Vancouver	R	12	15	—	—	55	50
Manitoba:	Winnipeg	R	7	8	—	—	23	24
New Brunswick:	Fredericton	R	15	15	—	—	30	25
Newfoundland:	St. Johns	R	30	21	—	—	74	41
Nova Scotia:	Halifax	R	11	13	—	—	26	25
Ontario:	Ft. William	R	17	15	—	—	39	28
	Ottawa	R	8	9	—	—	21	19

See footnotes at end of table.

Table 5. Concentrations of radionuclides in milk for August 1968 and 12-month period September 1967 through August 1968—continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)					
			Strontium-90		Iodine-131		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
Canada:—Cont.								
	Sault Ste. Marie	R	16	15	—	—	34	27
	Toronto	R	5	5	—	—	12	15
	Windsor	R	5	5	—	—	9	13
Quebec:	Montreal	R	7	10	—	—	22	20
	Quebec	R	13	13	—	—	32	28
Saskatchewan:	Regina	R	11	8	—	—	18	15
	Saskatoon	R	10	9	—	—	18	17
Central and South America:								
Columbia:	Bogota	P	3	0	0	0	0	2
Chile:	Santiago	P	0	0	0	0	0	0
Ecuador:	Guayaquil	P	0	0	0	0	0	2
Jamaica:	Mandeville	P	6	6	0	0	75	135
Venezuela:	Caracas	P	3	1	0	0	0	0
Canal Zone:	Cristobal[c]	P	3	1	7 (4)	1	11 (4)	9
Puerto Rico:	San Juan[c]	P	6	5	0 (3)	0	12 (3)	11

[a] P, pasteurized milk. R, raw milk.

[b] When an *individual sampling result* was equal to or less than the practical reporting level, a value of "0" was used for averaging. *Monthly averages* less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] U.S. PHS Pasteurized Milk Network Station. All other sampling locations are part of the State or national network.

[d] The practical reporting levels for these networks differ from the general ones given in the text. Individual results for these networks were equal to or less than the following practical reporting levels:

^{131}I: Colorado —25 pCi/liter
Michigan—14 pCi/liter
Oregon —15 pCi/liter

^{137}Cs: Colorado —25 pCi/liter
Oregon —15 pCi/liter
New York —20 pCi/liter
Washington—15 pCi/liter

^{90}Sr: New York—3 pCi/liter

NA no radionuclide analysis for the month.
NS, no sample collected for the month.
—Radionuclide analysis not routinely performed.

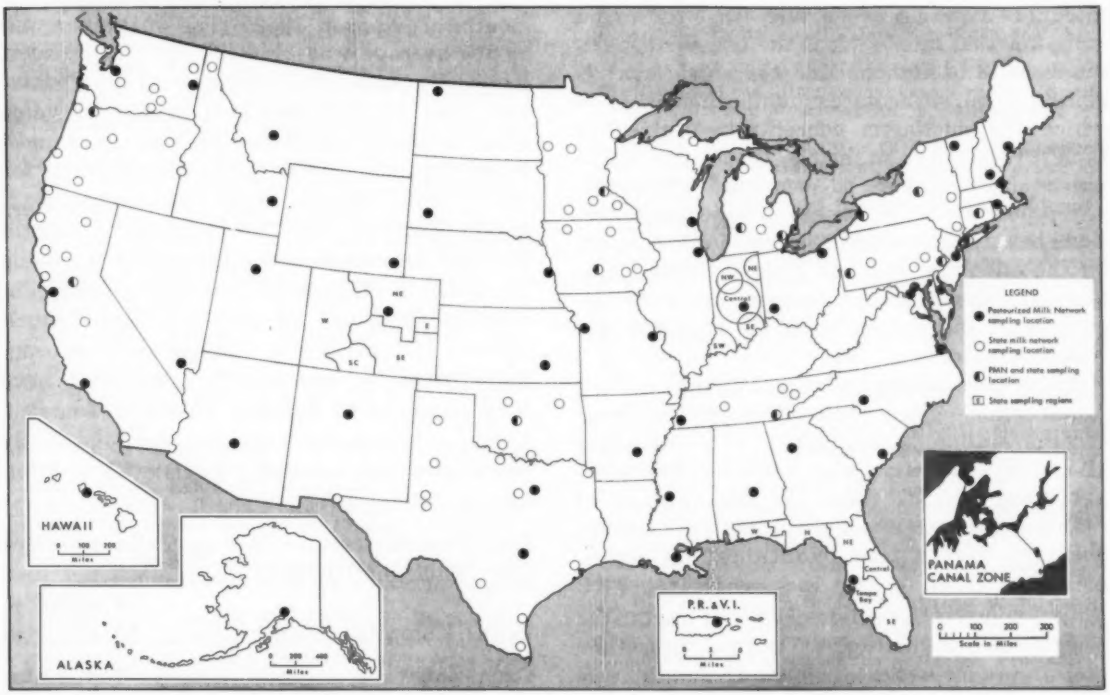

Figure 7. State and PHS milk sampling stations in the United States

stations and State stations are shown in figure 7.) The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of 0 is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level. This procedure is required in order to have numerical monthly concentration estimates that reflect all samples with detectable radioactivity, particularly when average annual intakes are developed.

If the occasion rises when an influx of new contamination occurs, particularly in the case of iodine–131, where sampling frequencies increase and/or the range of radionuclide concentration values for a month are significantly wider than the normal steady-state conditions, a column will be added after the appropriate monthly averages reflecting the maximum value for that month. It is the transient maximum value of radionuclide concentrations resulting from an acute contaminating event to which the maximum concentration given in table 4 [derived from the FRC protective action guides (PAG)] can be compared. However, any protective action based on these concentrations being reached will take place immediately on the observance of the high concentrations. Should such cases occur, a more complete discussion of the events would be required and will be provided.

The second column under each of the reported radionuclide gives the 12-month average for the station as calculated from preceding 12-month averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides (RPG's) apply (the control and regulation of normal peacetime uses of nuclear technology), the 12-month average serves as a basis for comparison.

Discussion of current data

In table 5, surveillance results are given for strontium–90, iodine–131, and cesium–137 for August 1968 and the 12-month period, September 1967–August 1968. Except where noted the monthly average represents a single sample for the sampling station. Strontium–89 and barium–140 data have been omitted from table 5, since levels at the great majority of the stations for August 1968 were below the respective practical reporting levels, however, the exceptions are shown in table 6.

Iodine–131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 3), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine–131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Strontium–90 monthly averages ranged from 0 to 25 pCi/liter in the United States for the month of August 1968. The maximum 12-month average was 21 pCi/liter (Little Rock, Ark.), representing 9.5 percent of the Federal Radiation Council radiation protection guide (table 3). Cesium–137 monthly averages ranged from 0 to 124 pCi/liter in the United States for the month of August 1968. The maximum 12-month average was 108 pCi/liter (Central Florida) representing 3.3 percent of the value calculated in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium–137 levels that have been observed in Florida (*16*) and Jamaica. Iodine–131 monthly averages were generally below practical reporting levels with the following exceptions:

Fla: West (State)	14 pCi/liter
Ohio: Cincinnati (PMN)	3 pCi/liter (4 samples)
Tenn: Knoxville (State)	13 pCi/liter
Canal Zone: Cristobal (PMN)	7 pCi/liter (4 samples)

Table 6. Reported strontium–89 and barium–140 concentrations in milk

Strontium-89		Barium-140			
Sampling location	Monthly average (pCi/liter)	Sampling location	Monthly average (pCi/liter)	Sampling location	Monthly average (pCi/liter)
Iowa: Des Moines (PMN)	6	Ariz: Phoenix (PMN)	3 (5)*	Kans: Wichita (PMN)	2 (4)
Columbia: Bogata (PAHO)	10	Calif: Del Norte (State)	14	Minn: Minneapolis (PMN)	2 (4)
Ecuador: Guayaquil (PAHO)	10	Fresno (State)	18	Mo: St. Louis (PMN)	1 (5)
Santiago: Chile (PAHO)	15	Humboldt (State)	17	Mont: Helena (PMN)	6 (4)
Venezuela: Caracas (PAHO)	15	Los Angeles (State)	14	Nebr: Omaha (PMN)	2 (5)
		Mendocino (State)	21	Nev: Las Vegas (PMN)	2 (4)
		San Diego (State)	17	N. Mex: Albuquerque (PMN)	3 (4)
		Santa Clara (State)	15	S. Dak: Rapid City (PMN)	3 (4)
		Sonoma (State)	23	Wash: Seattle (PMN)	6 (5)
		Fla: West (State)	14	Spokane (PMN)	2 (4)
		Southeast (State)	11	Canal Zone: Cristobal (PMN)	3 (4)
		Iowa: Des Moines (PMN)	2 (4)		

* Number of samples in parentheses.

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Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Division of Radiological Health
Bureau of Preventable Diseases
Florida State Board of Health

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
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Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

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Division of Environmental Sanitation
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Bureau of Radiological Health
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New York Department of Health

Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Health

Bureau of Environmental Health Services
Division of Radiological Health
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows.

Program	Period reported	Last presented
California Diet Study	July-October 1967	May 1968
Connecticut Standard Diet	January–June 1968	November 1968
Institutional Diet, PHS	January-March 1968	October 1968
Tri-City Diet, HASL	April-December 1967	June 1968

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence [1] of strontium–90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium–90, respectively.

Water sampling program	Period reported	Last presented
California	July–December 1967	November 1968
Coast Guard	January–December 1967	November 1968
Florida	1965–1966	July 1968
Minnesota	July–December 1967	October 1968
New York	June–December 1967	October 1968
Radiostrontium in Tap Water, HASL	January–June 1967	April 1968
Washington	July 1966–June 1967	August 1968

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Gross Radioactivity in Surface Waters of the United States, June 1968

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of the Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as part of the Water Pollution Surveillance System currently operated by the Federal Water Pollution Control Administration. Table 1 presents the current preliminary results of the alpha and beta radioanalyses. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported semiannually. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the November 1968 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations for 1958 through 1963 are published in annual compilations (*1–6*). Data for subsequent years are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data for comment. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. A dis-

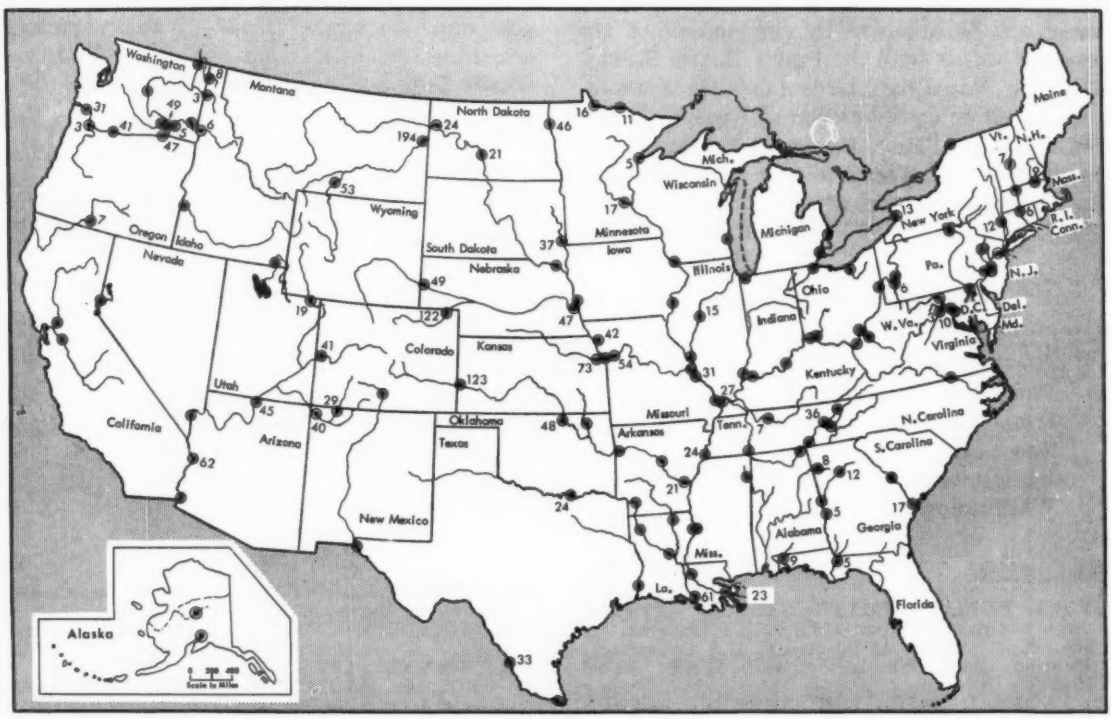

Figure 1. Sampling locations and associated total beta radioactivity (pCi/liter) in surface waters, June 1968

cussion of gross radioactivity per gram of solids for all stations of the Water Pollution Surveillance System for 1961 through 1965 has been presented (*7*). Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

The following stations showed alpha radioactivity on suspended or dissolved solids greater than 15 pCi/liter:

Arkansas River; Coolidge, Kans.
Big Horn River; Hardin, Mont.
Kansas River; Desoto, Kans.
North Platte River; Henry, Nebr.
South Platte River; Julesburg, Colo.
Yellowstone River; Sidney Mont.

Sidney, Mont. on the Yellowstone River also showed beta radioactivity on suspended solids above 150 pCi/liter.

Table 1. Radioactivity in raw surface water, June 1968

Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)			Station	Average alpha radioactivity (pCi/liter)			Average beta radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total		Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:							Mississippi River:						
Cedar Hill, N. Mex.	4	0	4	23	6	29	St. Paul, Minn.	0	2	2	4	13	17
Apalachicola River:							E. St. Louis, Ill.	4	1	5	22	9	31
Chattahoochee, Fla.	1	0	1	1	4	5	W. Memphis, Ark.	5	0	5	16	8	24
Arkansas River:							New Orleans, La.	5	1	6	15	8	23
Coolidge, Kans.	18	43	61	59	64	123	Missouri River:						
Ponca City, Okla.	5	2	7	28	20	48	Williston, N. Dak.	3	5	8	12	12	24
Pendleton Ferry, Ark.	2	0	2	10	11	21	Bismarck, N. Dak.	1	4	5	1	20	21
Atchafalaya River:							St. Joseph, Mo.	9	8	17	25	17	42
Morgan City, La.	10	1	11	50	11	61	Missouri City, Mo.	10	4	14	20	34	54
Big Horn River:							Monongahela River:						
Hardin, Mont.	16	6	22	36	17	53	Pittsburgh, Pa.	2	0	2	2	4	6
Big Sioux River:							North Platte River:						
Sioux Falls, S. Dak.	2	1	3	8	29	37	Henry, Nebr.	3	19	22	11	38	49
Chattahoochee River:							Ohio River:						
Atlanta, Ga.	1	0	1	1	11	12	Cairo, Ill.	6	1	7	20	7	27
Columbus, Ga.	1	0	1	2	3	5	Pend Oreille River:						
Clearwater River:							Albeni Falls Dam, Idaho	< 1	< 1	< 1	1	7	8
Lewiston, Idaho	< 1	< 1	< 1	3	3	6	Platte River:						
Clinch River:							Plattsmouth, Nebr.	4	7	11	18	29	47
Kingston, Tenn.[a]	0	0	0	2	34	36	Potomac River:						
Colorado River:							Washington, D.C.	1	0	1	7	3	10
Loma, Colo.	6	4	10	12	29	41	Rainy River:						
Page, Ariz.	0	8	8	2	43	45	International Falls, Minn.	0	0	0	2	9	11
Parker Dam, Calif-Ariz.	0	9	9	3	59	62	Baudette, Minn.	0	1	1	4	12	16
Columbia River:							Red River, North:						
Pasco, Wash.[a]	< 1	1	1	19	30	49	Grand Forks, N. Dak.	4	3	7	21	25	46
McNary Dam, Ore.	0	1	1	19	28	47	Red River, South:						
Bonneville, Ore.	0	1	1	7	34	41	Denison, Tex.	0	2	2	2	22	24
Clatskanie, Ore.	1	1	2	16	15	31	Rio Grande:						
Connecticut River:							Laredo, Tex.	1	4	5	5	28	33
Wilder, Vt.	0	0	0	2	5	7	San Juan River:						
Enfield Dam, Conn.	0	1	1	2	4	6	Shiprock, N. Mex.	10	2	12	30	10	40
Coosa River:							Savannah River:						
Rome, Ga.	< 1	1	1	3	5	8	Port Wentworth, Ga.[a]	1	< 1	1	5	12	17
Cumberland River:							Shenandoah River:						
Cheatham Lock, Tenn.	0	1	1	2	5	7	Berryville, Va.	0	1	1	0	3	3
Escambia River:							Snake River:						
Century, Fla.	1	1	2	4	5	9	Ice Harbor Dam, Wash.	0	0	0	1	4	5
Great Lakes:							South Platte River:						
Duluth, Minn.	0	0	0	1	4	5	Julesburg, Colo.	5	40	45	22	100	122
Detroit, Mich.	0	0	0	2	11	13	Spokane River:						
Green River:							Post Falls Dam, Idaho	0	0	0	2	1	3
Dutch John, Utah	0	6	6	1	18	19	Willamette River:						
Hudson River:							Portland, Ore.	0	0	0	1	2	3
Poughkeepsie, N.Y.	0	0	0	7	5	12	Yellowstone River:						
Illinois River:							Sidney, Mont.	28	1	29	165	29	194
Peoria, Ill.	1	2	3	5	10	15							
Kansas River:							Maximum	28	43	61	165	100	194
DeSoto, Kans.	25	4	29	51	22	73							
Klamath River:							Minimum	0	0	0	1	1	3
Keno, Ore.	1	1	2	1	6	7							
Merrimack River:													
Lowell, Mass.	0	0	0	3	6	9							

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides.

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Radioactivity in Surface Waters of the Colorado River Basin, 1967

Colorado River Basin Water Quality Control Project
Federal Water Pollution Control Administration
Department of the Interior

The Radium Monitoring Network is a surface water surveillance system currently consisting of 20 sampling stations located throughout the Colorado River basin (figure 1). During initial stages of the surveillance program, the system consisted of 27 sampling stations. The purpose of this network is to provide a continuous assay of basin river water radioactivity resulting primarily from uranium mining and milling industry waste discharges. Recently, the types of sample analyses were expanded from radium–226 and uranium to include gross alpha radioactivity, gross beta radioactivity, thorium alpha radioactivity, lead–210 and strontium–90, to provide a more comprehensive picture of contributions of radiological contaminants to surface waters of the Colorado River Basin by the uranium industry and by fallout from nuclear testing. The network was established following a 1957 conference on uranium milling wastes, attended by representatives of the States of Arizona, Colorado, New Mexico, and Utah, and the U.S. Public Health Service. A summary of data collected through 1966 was published in May 1968 (*1*).

Sampling procedures

Depending on individual station parameters, Radium Monitoring Network (RMN) samples are collected as either automatic or grab samples. Grab samples are collected once or three times per week and automatic samplers collect 21 milliliter portions every hour. The samples are sent as collected to the Colorado River Basin Water Quality Control Project Laboratory where they are composited, filtered and analyzed for the desired radionuclides.

Radium–226 with the lowest recommended maximum permissible concentration in water of all radionuclides, has been the radioactive contaminant of greatest concern in uranium discharges. Consequently, initial and primary emphasis was placed on the analysis for radium only. In October 1963, uranium determinations were added. Beginning in July 1963, samples from selected stations were combined into quarterly composites for gamma-ray spectroscopy and analyzed for gross alpha, gross beta, strontium–90, thorium alpha, and lead–210 radioactivities. Some determinations for polonium–210 were also performed.

Analytical methods

Water samples are composited and filtered through 0.45 micron-membrane filters as soon as possible after the samples for the compositing period are received. After filtration, samples are acidified with a 2 percent by volume 12 N hydrochloric acid and radiochemical determinations are then performed on the filtered water.

Radium–226 is determined by an emanation method (*2*). Lead–210 is determined by an iodine-dithiozone extraction method (*3*). Uranium is determined by a fluorometric method, using a sodium carbonate-potassium carbonate-sodium fluoride flux (*4*). Gross alpha and beta radioactivity determinations are made on dried dissolved solids from the waters, using appropriate correction factors for self-absorption.

Strontium–90 is isolated by coprecipitation with calcium and magnesium carbonate. It is absorbed in an ion exchange column and the yttrium–90 which grows is eluted and measured. Gross gamma-ray determinations are done using a sodium iodide crystal as a detector and a scaler as the recording device.

Alpha-particle emitting thorium isotopes are determined by coprecipitation with ferric hydroxide and lanthanum fluoride followed by extraction with thenoyltrifluoroacetone, mounting, and alpha-particle counting.

Results

Radium–226 and uranium concentrations continue to average well below recommended maximum concentrations at most stations. A summary of radium–226 and uranium determinations on RMN samples for 1967 is given in tables 1 and 2. During 1967, radium–226

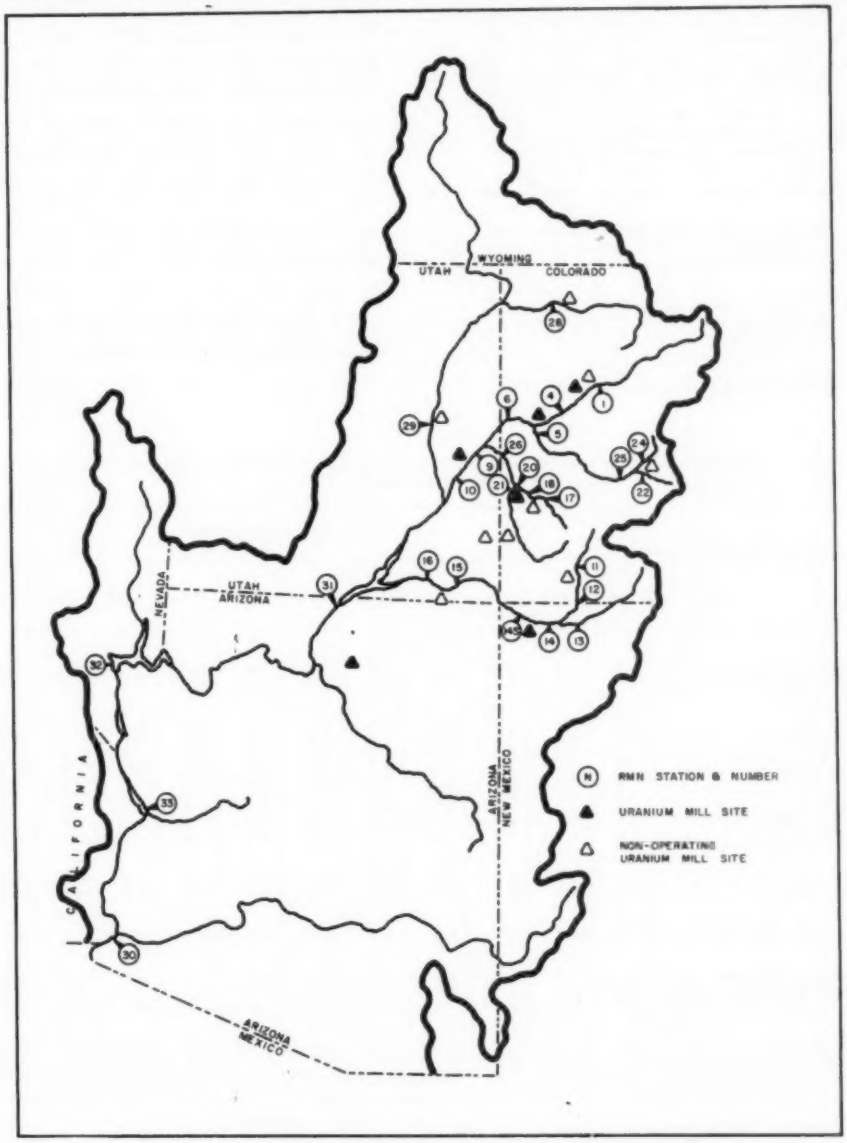

Figure 1. Colorado River Basin radium monitoring network

Table 1. Radium-226 in surface waters of the Colorado River basin averages January-December 1967

Sampling station number and location	Concentration (pg/liter)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly average
Animas River:													
#11 above Durango, Colo	0.05	0.05	0.04	0.05	0.03	0.04	0.03	0.05	0.06	0.06	0.04	0.04	0.05
#12 Colo.-N. Mex. State line	.09	.08	.05	.09	.11	.10	.13	.09	.12	.11	.08	.08	.09
Colorado River:													
#1 at Silt, Colo	.29	.26	.20	.15	.10	.06	.13	.21	.21	.24	.26	.27	.20
#4 at De Beque, Colo	.26	.21	.23	.18	.13	.08	.14	.20	.21	.21	.22	.24	.19
#6 at Fruita, Colo	.16	.16	.16	.12	.18	.16	.22	.29	.15	.17	.16	.13	.17
#9 above Moab, Utah	.31	.25	.23	.20	.26	.17	.52	.30	.20	.17	.41	.33	.28
#10 below Moab, Utah	3.00	1.2	.99	.48	.40	.26	.33	.32	1.12	.96	.99	1.10	.93
#31 at Page, Ariz	.10	NS	.04	NS	NS	.07	.20	.19	.20	.18	.17	.15	.14
#32 Lake Mead, Nev	.41	.35	.36	.29	.30	.31	.30	.27	.29	.27	.27	.36	.31
#33 Lake Havasu, Calif	.29	.40	.38	.34	.34	.35	.37	.32	.33	.32	.31	.28	.34
#30 at Yuma, Ariz	.16	.15	.18	.19	.13	.20	.22	.20	.12	.15	.12	.20	.17
Dolores River:													
#21 at Bedrock, Colo	.54	.20	.26	.25	.16	.36	1.00	.46	.62	.83	.78	.54	.50
#26 at Gateway, Colo	1.70	2.30	1.10	1.10	.82	1.10	1.10	1.10	.82	.85	1.40	1.30	1.22
Gunnison River:													
#5 at Grand Junction, Colo	.04	.09	.06	.08	.06	.08	.12	.15	.09	.07	.08	.06	.08
San Juan River:													
#14 below Farmington, N. Mex	.05	.04	.04	.05	.06	.04	.09	.09	.07	.05	.11	.07	.06
#15 above Mexican Hat, Utah	.05	.05	.05	.08	.07	.12	.12	.08	.10	.09	.06	.08	.08
#16 below Mexican Hat, Utah	.08	.05	.06	.08	.06	.09	.12	.10	.10	.10	.07	.06	.08
San Miguel River:													
#17 above Naturita, Colo	.04	.06	.05	.04	.03	.02	.04	.06	.05	.04	.03	.04	.04
#18 above Uravan, Colo	.09	.09	.15	.09	.17	.11	.10	.25	.13	.11	.08	.06	.12
#20 below Uravan, Colo	1.80 (4)	3.15 (4)	1.10 (5)	.94 (4)	1.03 (4)	2.01 (5)	.42 (4)	.50 (4)	.64 (5)	.70 (4)	2.42 (5)	4.15 (4)	1.57

NS, no sample.
Number in parentheses indicates number of samples.

Table 2. Uranium in surface waters of the Colorado River basin averages January-December 1967

Sampling station number and location	Concentration (pg/liter)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly average
Animas River:													
#11 above Durango, Colo	1.4	1.2	2.0	1.5	0.7	0.6	0.8	1.6	1.4	2.1	2.3	1.7	1.4
#12 Colo.-N. Mex. State line	2.5	1.9	3.1	2.2	1.1	1.1	3.0	1.9	2.2	3.6	3.5	2.9	2.4
Colorado River:													
#1 at Silt, Colo	3.2	3.1	4.0	2.2	1.5	1.2	1.8	2.9	3.7	3.0	4.2	3.4	2.9
#4 at De Beque, Colo	4.4	5.9	4.0	2.6	1.9	1.4	2.2	4.1	5.0	5.8	5.8	6.0	4.1
#6 at Fruita, Colo	9.5	9.0	8.0	6.2	5.2	3.9	7.1	11.0	11.0	14.0	9.1	7.3	8.4
#9 above Moab, Utah	11.0	11.0	9.0	6.4	6.9	3.8	8.5	12.0	13.0	14.0	11.0	8.7	9.6
#10 below Moab, Utah	16.0	14.0	12.0	8.5	8.4	4.3	7.2	14.0	18.0	18.0	14.0	11.0	12.1
#31 at Page, Ariz	5.2	NS	6.4	NS	NS	5.1	6.6	6.9	4.4	5.5	5.6	5.6	5.7
#32 Lake Mead, Nev	6.7	7.1	7.0	7.2	6.4	6.5	6.6	6.9	7.1	7.3	6.8	7.1	6.9
#33 Lake Havasu, Calif	7.5	7.2	8.0	8.3	7.3	7.4	6.2	7.1	6.9	6.8	7.4	7.1	7.3
#30 at Yuma, Ariz	2.0	5.9	7.4	7.4	6.8	6.5	6.5	7.6	5.1	5.8	6.0	5.6	6.1
Dolores River:													
#21 at Bedrock Colo	7.0	6.0	6.4	6.0	2.7	4.1	12.0	11.0	10.0	14.0	15.0	14.0	9.0
#26 at Gateway, Colo	28.0	29.0	17.0	14.0	10.0	9.5	11.0	14.0	19.0	36.0	30.0	32.0	20.8
Gunnison River:													
#5 at Grand Junction, Colo	15.0	11.0	9.1	5.4	4.8	7.0	14.0	13.0	13.0	15.0	7.9	5.6	10.1
San Juan River:													
#14 below Farmington, N. Mex	2.1	3.1	2.3	3.2	2.5	2.6	5.1	4.1	3.7	4.3	4.1	3.4	3.4
#15 above Mexican Hat, Utah	6.3	6.6	4.3	7.0	6.4	3.4	6.8	6.1	5.2	8.5	6.6	6.2	6.1
#16 below Mexican Hat, Utah	5.2	4.4	4.1	7.0	6.6	4.3	7.0	5.9	5.8	9.0	8.3	5.8	6.1
San Miguel River:													
#17 above Naturita, Colo	2.7	5.0	2.4	3.0	1.5	1.7	2.5	2.0	4.1	3.1	3.8	5.1	3.1
#18 above Uravan, Colo	4.7	5.0	3.7	3.5	2.8	2.7	2.7	4.5	5.1	3.7	5.0	5.2	4.1
#20 below Uravan, Colo	8.6 (4)	8.4 (4)	12.8 (5)	5.7 (4)	4.9 (4)	12.5 (5)	11.5 (4)	27.6 (4)	14.6 (5)	11.8 (4)	14.5 (5)	43.3 (4)	14.7

NS, no sample.
Number in parentheses indicates number of samples.

and uranium concentrations remained low because of the shutdown of the Durango, Colo., uranium mill in 1963.

Samples taken in the Colorado River at Moab, Utah, contained the most elevated radium–226 and uranium concentrations. The only radium–226 samples having an excess of 1.0 picogram per liter in the Colorado River were taken below Moab, Utah. The mean annual concentration of radium–226 was 0.93 picograms per liter from 0.39 for the previous year at Moab, Utah. The concentrations of radium–226 in the Colorado River at Page, Ariz., Lake Mead, Lake Havasu, and the U.S.-Mexican border showed either no significant change or slightly lower values.

Elevated radium and uranium concentrations in the Dolores River at Gateway, Colo., are attributed primarily to waste discharges from the mill at Urvan, Colo. Only the stations at Gateway and below Urvan, Colo., had annual radium averages above 1.0 picogram per liter. The mean annual concentration of radium–226 below Urvan, Colo., was down to 1.57 picograms per liter from 1.92 for the previous year. The mean annual concentrations of uranium at Gateway and below Urvan, Colo., decreased 2.6 micograms and 6.7 from the previous year respectively. The maximum concentration of uranium was 55 μg/liter detected in a sample from the Miguel River below Urvan, Colo.

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(*4*) GRINALDI, F. S., I. MAY, M. H. FLETCHER, and J. PITCOMB. Collected papers on methods of analysis for uranium and thorium, USGS Bulletin 1006. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1954).

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson in 1962 and is summarized in the January 1964 issue of *Radiological Health Data*. In addition to those programs presented in this issue, the following program was previously covered in *Radiological Health Data and Reports*.

Network	Period	Issue
HASL Fallout Network	July–December 1967	September 1968

1. Radiation Alert Network August 1968

National Center for Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate National Center for Radiological Health officials by mail or telephone depending on levels found. Compilation of the daily field estimates is reported elsewhere on a monthly basis (1). A detailed description of the sampling and analytical procedures was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during August 1968. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

REFERENCE

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Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, August 1968

Station location		Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Last profile in RHD▲R	Number of samples	Precipitation			
								Total depth (mm)	Field estimation of depotsition		
		Air	Maximum	Minimum	Average[a]				Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	22	6	0	2	Sept 68	6	79	6	79	36
Alaska:	Adak	29	4	1	2	Apr 68	(c)				
	Anchorage	14	0	0	0	Oct 68	(c)				
	Attu Island	(b)				May 68	(c)				
	Fairbanks	11	2	0	1	Nov 68	4	22	4	22	29
	Juneau	13	0	0	0	Dec 68	2	34	2	34	0
	Kodiak	20	2	0	1	Mar 68	(c)				
	Nome	(b)				July 68	(c)				
	Point Barrow	18	3	0	1	June 68	(c)				
	St. Paul Island	14	1	1	1	Aug 68	(c)				
Ariz:	Phoenix	20	11	0	4	Dec 68	1	3	0	0	(c)
Ark:	Little Rock	10	6	1	2	Oct 68	1	14	1	14	0
Calif:	Berkeley	21	1	0	0	Mar 68	1	3	1	3	0
	Los Angeles	(b)				July 68	(c)				
C.Z:	Ancon	17	0	0	0	Mar 68	(c)				
Colo:	Denver	19	5	1	3	Mar 68	4	33	(d)		
Conn:	Hartford	22	1	0	0	Nov 68	6	44	6	44	10
Del:	Dover	22	1	0	1	Sept 68	(c)				
D.C:	Washington	17	2	0	1	June 68	4	76	3	59	1
Fla:	Jacksonville	20	1	0	1	Oct 68	7	119	7	119	184
	Miami	20	1	0	0	Nov 68	6	153	6	153	0
Ga:	Atlanta	21	2	1	1	Aug 68	3	60	3	60	30
Guam:	Agana	17	1	0	1	Sept 68	(c)				
Hawaii:	Honolulu	31	1	0	1	May 68	(c)				
Idaho:	Boise	20	5	0	3	May 68	5	89	4	68	0
Ill:	Springfield	7	8	4	5	June 68	1	63	0	0	(c)
Ind:	Indianapolis	21	5	0	1	Aug 68	7	197	7	197	196
Iowa:	Iowa City	20	3	0	1	Mar 68	3	16	3	16	0
Kans:	Topeka	21	3	0	1	Oct 68	9	194	9	194	0
Ky:	Frankfort	6	7	1	2	June 68	(c)				
La:	New Orleans	12	1	0	0	June 68	4	42	(d)		
Maine:	Augusta	22	1	0	1	Dec 68	4	43	4	43	0
Md:	Baltimore	22	2	0	1	Nov 68	6	48	6	48	3
	Rockville	17	3	0	1	May 68	1	95	(d)		
Mass:	Lawrence	17	1	0	0	Sept 68	5	25	4	9	1
	Winchester	22	2	0	1	Apr 68	4	46	4	46	0
Mich:	Lansing	22	4	0	2	May 68	7	62	7	62	182
Minn:	Minneapolis	17	1	0	0	Sept 68	4	35	4	35	0
Miss:	Jackson	21	3	0	1	Dec 68	6	158	5	144	176
Mo:	Jefferson City	21	4	0	1	Aug 68	3	33	3	33	0
Mont:	Helena	23	5	0	3	Apr 68	5	6	5	6	6
Nebra:	Lincoln	15	4	0	2	Aug 68	5	42	5	42	0
Nev:	Las Vegas	20	5	1	3	Nov 68	(c)				
N.H:	Concord	19	3	0	1	June 68	(c)				
N.J:	Trenton	22	4	1	2	Dec 68	5	81	5	81	37
N. Mex:	Santa Fe	22	1	0	1	Apr 68	6	45	5	40	0
N.Y:	Albany	22	2	0	1	Aug 68	6	54	6	54	37
	Buffalo	21	1	0	1	Mar 68	(c)				
	New York City	21	1	1	1	Apr 68	(c)				
N.C:	Gastonia	18	8	2	5	Mar 68	(c)				
N. Dak:	Bismarck	24	8	0	2	June 68	9	144	9	144	0
Ohio:	Cincinnati	(b)				Sept 68	(c)				
	Columbus	19	5	0	2	Dec 68	4	85	3	51	0
	Painesville	20	2	0	1	Nov 68	7	26	7	26	5
Okla:	Oklahoma City	13	3	0	1	May 68	3	51	3	51	0
	Ponca City	14	3	0	2	Nov 68	4	94	3	69	35
Ore:	Portland	21	1	0	0	Aug 68	8	61	8	61	0
Pa:	Harrisburg	(b)				Aug 68	(c)				
P.R:	San Juan	(b)				Dec 68	(c)				
R.I:	Providence	21	4	0	1	May 68	6	70	5	57	35
S.C:	Columbia	21	2	0	1	Apr 68	3	43	3	43	6
S. Dak:	Pierre	14	7	2	5	Dec 68	(c)				
Tenn:	Nashville	17	2	0	1	May 68	3	42	3	42	0
Tex:	Austin	12	11	0	3	Sept 68	(c)				
	El Paso	8	4	0	1	June 68	(c)				
Utah:	Salt Lake City	31	3	0	1	July 68	9	77	9	77	26
Vt:	Barre	10	3	1	1	Oct 68	2	26	2	26	0
Va:	Richmond	18	1	0	1	Oct 68	4	93	4	93	47
Wash:	Seattle	25	3	0	0	Oct 68	9	99	(d)		
S	Spokane	22	2	0	1	Sept 68	6	30	6	30	17
W. Va:	Charleston	21	2	0	1	Apr 68	10	124	10	124	32
Wisc:	Madison	23	2	0	1	Oct 68	6	129	6	129	71
Wyo:	Cheyenne	22	7	1	4	Nov 68	5	17	5	17	31
Network summary		1,265	11	0	1		5	66	5	64	32

[a] The monthly average is calculated by weighting the field estimates of individual air samples with lengtn of sampling period.
[b] Indicates no report received (Air samples received without field estimate data are not considered by the data program.
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were received.

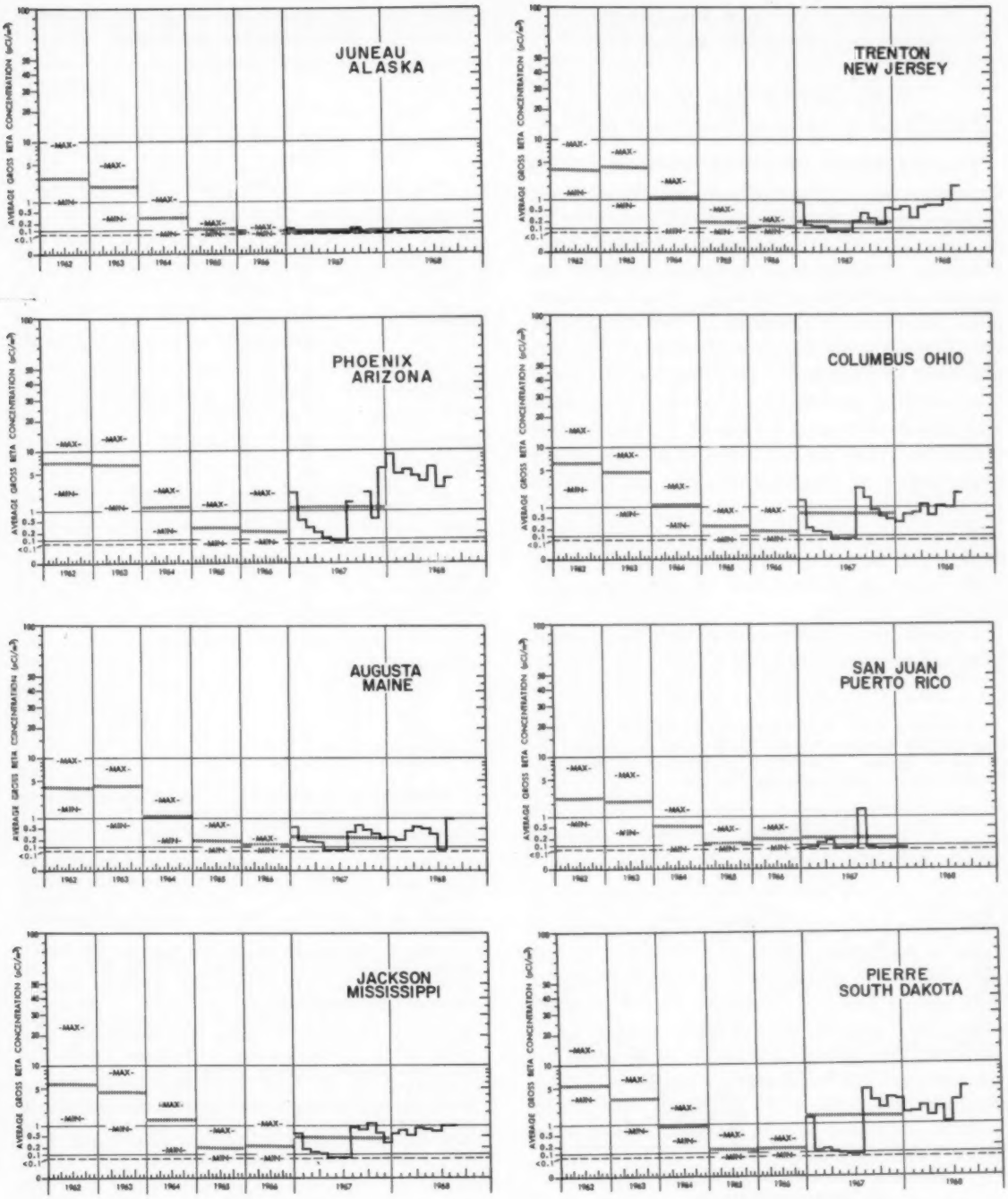

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1962–January 1968

2. Canadian Air and Precipitation Monitoring Program, August 1968

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the April 1968 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for August 1968 are presented in table 2.

[1] Prepared from information and data in the September 1968 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

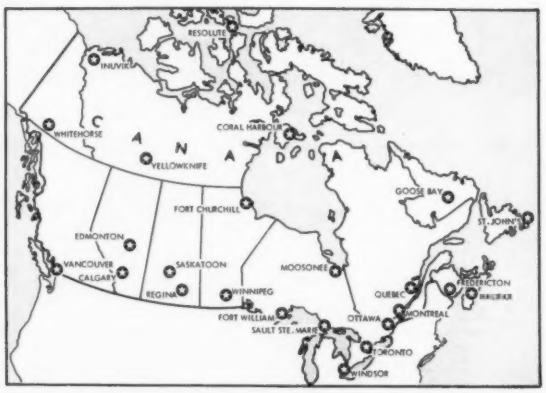

Figure 3. Canadian air and precipitation sampling stations

Table 2. Canadian gross beta radioactivity in surface air and precipitation, August 1968

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentrations (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	0.3	0.0	0.1	131	3.4
Coral Harbour	21	.1	.0	.0	47	2.4
Edmonton	31	.2	.0	.1	55	3.7
Ft. Churchill	30	.2	.0	.1	58	3.4
Ft. William	31	.2	.0	.1	32	3.4
Fredericton	31	.2	.0	.1	47	2.7
Goose Bay	31	.2	.0	.1	NS	NS
Halifax	30	.2	.0	.1	51	2.7
Inuvik	31	.2	.0	.1	108	2.9
Montreal	31	.3	.0	.1	55	7.1
Moosonee	31	.2	.0	.1	11	1.7
Ottawa	31	.2	.0	.1	35	3.7
Quebec	31	.2	.0	.1	62	2.9
Regina	31	.2	.0	.1	39	4.4
Resolute	26	.1	.0	.1	25	1.1
St. John's, Nfld.	31	.2	.0	.1	21	3.6
Saskatoon	30	.2	.0	.1	50	4.1
Saulte Ste Marie	31	.3	.0	.1	40	3.8
Toronto	31	.3	.0	.1	16	2.7
Vancouver	31	.2	.0	.1	50	2.5
Whitehorse	31	.2	.0	.1	39	1.9
Windsor	31	.2	.0	.1	22	1.6
Winnipeg	31	.3	.0	.1	19	2.8
Yellowknife	31	.2	.0	.1	60	1.0
Network summary	726	0.3	0.0	0.1	47	3.0

NS, no sample.

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3. Pan American Air Sampling Program August 1968

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling locations are shown in figure 5. Analytical techniques were described in the January 1968 *Radiological Health Data and Reports*. The August 1968 air monitoring results from the participating countries are given in table 4. A noticeable increase in the monthly average concentration of gross beta radioactivity occurred in all of the countries, and fresh fission products were identified by gamma spectroscopy in several samples.

Table 4. Summary of gross beta radioactivity in Pan American surface air, August 1968

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average*
Argentina: Buenos Aires	3	0.72	0.46	0.55
Bolivia: La Paz	14	12.51	1.06	5.03
Chile: Santiago	28	10.12	.16	1.70
Colombia: Bogata	17	1.32	.02	.66
Ecuador: Guayaquil	22	4.57	.78	1.94
Guyana: Georgetown	9	.98	.08	.46
Jamaica: Kingston	14	.22	.06	.12
Peru: Lima	3	3.30	2.10	2.57
Venezuela: Caracas	21	1.79	.12	.56
West Indies: Trinidad	18	1.11	.07	.29
Pan American summary	149	12.51	0.02	1.37

* The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

Figure 5.— PAN AMERICAN AIR SAMPLING PROGRAM STATIONS

Figure 5. Pan American Air Sampling Program stations

5. Plutonium in Airborne Particulates and Precipitation, July–December 1967

National Center for Radiological Health U.S. Public Health Service

The Radiation Alert Network (RAN) of the National Center for Radiological Health, Public Health Service, routinely analyzes airborne particulate and precipitation samples from selected RAN stations for plutonium. The airborne particulate and precipitation analyses were initiated in November 1965 and August 1966, respectively, and the results through June 1967 have been previously reported (*1–7*).

Air filters from 11 RAN stations are analyzed for plutonium. A monthly composite is made of one-half of each individual air filter from each of the 11 stations and sent to the PHS Northeastern Radiological Health Laboratory (NERHL) for analysis. Eight RAN stations submit complete collections of precipitation for plutonium analysis. An 8 liter (or whatever is available) aliquot of the monthly collection for each of the 8 stations is forwarded to the NERHL for analysis.

Beginning with the August 1967 samples, the air filters and precipitation samples have been analyzed at the NERHL for plutonium–238 and plutonium–239. The air filters are dry-ashed

at 500°C. The ash is treated with nitric hydrofluoric and perchloric acids to volatilize silica, destroy any remaining organic matter and solubilize the sample. Precipitation samples are filtered through an 0.45 micron membrane paper to remove suspended solids and the solution is evaporated to a small volume. Suspended solids are subject to the same acid treatment as described for the air filter samples and then combined with the evaporated precipitation. Plutonium–236 tracer is added to the samples, the plutonium reduced to the +3 oxidation state with hydroxylamine hydrochloride and coprecipitated with lanthanum fluoride. The lanthanum fluoride is converted to lanthanum hydroxide, dissolved in 7.2 M nitric acid and the plutonium oxidized to the +4 oxidation state with sodium nitrite. The solutions are then passed over an anion exchange resin in the nitrate form. The resin is washed with additional 7.2 M nitric acid and then with 9 M hydrochloric acid. The plutonium is eluted from the resin with a mixture of 0.36 M hydrochloric acid and 0.01 M hydrofluoric acid, electroplated onto a stainless-steel planchet from a sulfuric acid-ammonium sulfate electrolyte, and counted in an alpha-particle spectrometer.

The energies of the alpha particles from plutonium–239 and plutonium–240 are not sufficiently different to be separated by alpha-particle spectrometry. Consequently, the reported plutonium–239 activities represent the sum of the activities of plutonium–239 and plutonium–240.

The samples are usually counted for at least 1,000 minutes. Reagent blanks containing plutonium–236 tracer are run concurrently with the samples. A silicon surface barrier detector with an active area of 4.5 cm^2 is used. With the sample electroplated onto a 3.1 cm^2 area, the counting efficiency is 31 percent and the resolution 75 keV (full width half maximum).

The alpha particle activity of plutonium–238 and plutonium–239 is converted to picocuries of the radionuclide per sample from the following equation:

$$^{238}\text{Pu (or } ^{239}\text{Pu}) = \frac{(A-B)\,C}{(D-E)}$$

^{238}Pu (or ^{239}Pu) = pCi per sample of plutonium-238 (or plutoniun-239)

where,

A = gross counts per minute (CPM) in plutonium–238 (or plutonium–239) spectral region,

B = reagent blank CPM in plutonium–238 (or plutonium–239) spectral region,

C = pCi plutonium–236 added,

D = gross CPM in plutonium–236 spectral region,

and,

E = background CPM in plutonium–236 spectral region.

Using these procedures, the minimum detectable activities for plutonium–238 and plutonium–239 are .020 pCi per sample and .015 pCi sample, respectively.

Prior to August 1967, the air filters and precipitation samples were analyzed for total plutonium at RAN headquarters in Rockville, Md. The analytical methodology for processing these samples has been described in earlier reports (*1*, *6*).

The results for July through December 1967 are presented in tables 5 and 6. ND (not detectable) has been used to indicate samples containing plutonium–238 or plutonium–239 activities less than or equal to the appropriate minimum detectable activities. Sample size varies, generally ranging from 20,000 to 30,000 cubic meters of air for the air filter samples, and from 2 to 8 liters for the precipitation samples.

REFERENCES

(*1*) RUSSELL, J., H. LEVINE, R. SCHNEIDER. Plutonium in airborne particulates, November 1965 through March 1966. Radiol Health Data Rep 7:483–484 (August 1966).

(*2*) DIVISION OF RADIOLOGICAL HEALTH. Plutonium in airborne particulates, April–June 1966. Radiol Health Data Rep 7:666–667 (November 1966).

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulate, July–September 1966. Radiol Health Data Rep 8:108–109 (February 1967).

Table 5. Plutonium in airborne particulates, July–November 1967

	Buffalo	Gastonia	Rockville	Pierre	New Orleans	Austin	Denver	Anchorage	Phoenix	Honolulu	Seattle
Total plutonium: (fCi/m³)											
July	0.061	.052	.049	.077	.038	.034	.049	.031	.031	.020	.032
Plutonium 238: (fCi/m³)											
August	.0130	ND	ND	.0200	.0108	.0334	.0394	ND	.1094	NA	.0061
September	ND	.0125	.0152	.0117	.0101	.0132	.0156	.0027	NA	.0060	.0105
October	.0064	.0033	.0049	.0058	.0158	.0100	.0126	.0071	.0075	.0075	.0050
November	ND	.0037	.0029	.0056	.0056	.0024	.0076	.0108	.0108	.0066	ND
Plutonium-239: (fCi/m³)											
August	.0183	.0139	.0264	.0321	.0127	.0156	.0271	.0012	.0243	NA	.0092
September	.0177	.0202	.0189	.0219	.0221	.0140	.0172	.0042	NA	.0102	.0180
October	.0144	.0089	.0104	.0138	.0239	.0105	.0174	.0021	.0171	.0075	.0103
November	.0046	.0068	.0026	.0032	.0087	.0049	.0664	.0414	.0092	.0053	ND
$^{238}Pu/^{239}Pu$:											
August	1.41	----------	----------	1.61	1.18	0.47	0.69	----------	0.22	----------	1.51
September	----------	1.61	1.24	1.87	2.18	1.06	1.10	1.56	----------	1.70	1.71
October	1.78	2.70	2.12	2.38	1.82	1.95	1.38	0.30	2.28	1.00	2.06
November	----------	1.84	.90	1.33	1.55	2.04	8.74	3.83	1.39	2.12	----------

NA, no analysis.
ND, nondetectable.

Table 6. Plutonium in precipitation, July–December 1967 [a]

	Gastonia	Rockville	Pierre	New Orleans	Austin	Denver	Honolulu	Seattle
Precipitation depth: (mm)								
July	142	NS	1	207	9	102	25	NS
August	145	NS	NS	117	66	13	85	NS
September	45	NS	28	52	169	8	4	36
October	35	44	NS	22	85	29	37	86
November	33	62	NS	22	61	5	70	86
December	69	89	NS	65	61	5	85	42
Concentration (pCi/liter)								
Total plutonium:								
July	0.0086	----------	NA	0.0071	0.1970	0.0152	0.0147	----------
Plutonium-238:								
August	NA	----------	----------	----------	NA	NA	NA	----------
September	ND	----------	NA	ND	ND	ND	NA	0.0030
October	ND	NA	----------	.0023	ND	ND	NA	ND
November	NA	ND	----------	ND	NA	.0124	NA	ND
December	ND	ND	----------	ND	ND	ND	NA	.0033
Plutonium-239								
August	ND	----------	----------	ND	ND	NA	ND	----------
September	ND	----------	NA	ND	ND	.0073	NA	.0022
October	ND	.0030	----------	.0072	ND	.0034	.0031	.0018
November	ND	.0025	----------	ND	ND	.0075	ND	.0018
December	ND	ND	----------	ND	ND	ND	NA	.0045
Deposition (pCi/m²)								
Total plutonium:								
July	1.22	----------	NA	1.47	1.77	1.55	0.51	----------
Plutonium-238:								
August	NA	----------	----------	NA	NA	NA	NA	----------
September	ND	----------	NA	ND	ND	ND	NA	.11
October	ND	NA	----------	.05	ND	ND	NA	ND
November	NA	ND	----------	ND	NA	.06	NA	ND
December	ND	ND	----------	ND	ND	ND	NA	.14
Plutonium-239:								
August	ND	----------	----------	ND	ND	NA	ND	----------
September	ND	----------	NA	ND	ND	.06	NA	.08
October	ND	.13	----------	.16	ND	.10	0.11	.15
November	ND	.16	----------	ND	ND	.04	ND	.06
December	ND	ND	----------	ND	ND	ND	NA	.19

[a] The basic finding is the concentration (pCi/liter). This figure is multiplied by the depth of precipitation for the month (mm) to obtain the total deposition (pCi/m²). One liter of water is collected when one mm of precipitation falls on one square meter.
NA, no analysis.
ND, not detectable (see text).
NS, no sample.

(4) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates, October–December 1966. Radiol Health Data Rep 8:288–289 (May 1967).

(5) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates, January–March 1967. Radiol Health Data Rep 8:534 (September 1967).

(6) LEVINE, H., W. P. KIRK, H. J. L. RECHEN. Plutonium and strontium–90 in precipitation, August 1966 through March 1967. Radiol Health Data Rep 8:574–576 (October 1967).

(7) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Plutonium in airborne particulates and precipitation and strontium–90 in precipitation, April–June 1967. Radiol Health Data Rep 8:662–663 (November 1967).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, bovine thyroid sampling, Alaskan surveillance and environmental monitoring around nuclear facilities.

Radionuclides in Alaskan Caribou and Reindeer March–May 1968

National Center for Radiological Health
U.S. Public Health Service

Under a cooperative agreement between the Alaskan Department of Health and Welfare, the Alaskan Department of Fish and Game, and the U.S. Public Health Service, an active program of caribou and reindeer sampling and analysis was undertaken in 1963 to aid in the assessment of radionuclide intake of Alaskan residents. This joint sampling activity was continued based on the results of a limited sampling effort conducted by these groups in 1962.

Through the second quarter of 1964, the sampling was confined to the three principal caribou herds and one privately-owned reindeer herd. This program was expanded in September 1964, when the sampling of additional privately-owned and government-owned reindeer herds was begun through the assistance of the Fish and Wildlife Service and the Bureau of Indian Affairs, Department of Interior.

Figure 1 shows the locations of the caribou

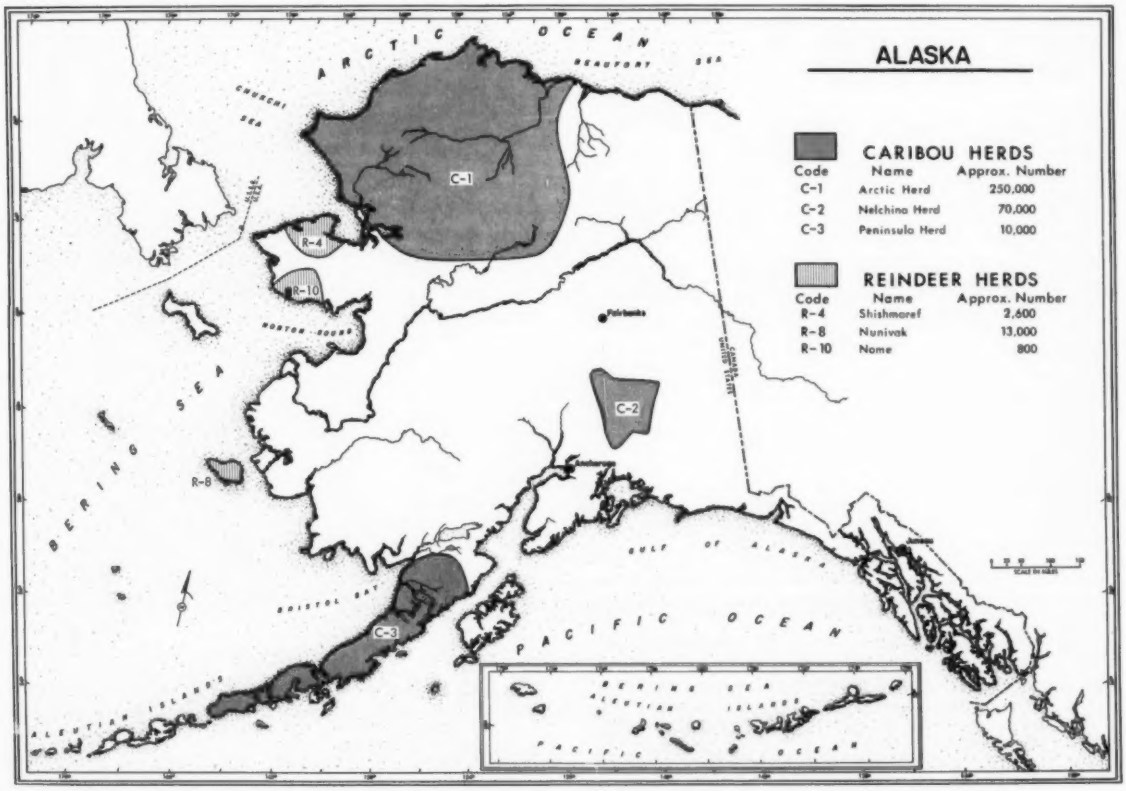

Figure 1. Locations of caribou and reindeer herds sampled in Alaska

Table 1. Radionuclide concentrations in muscle and rumen of Alaskan caribou and reindeer, March–May 1968

Herd and sampling locations [a]	Collection date, 1968	Sex	Age (years)	Muscle (pCi/kg wet weight)			Rumen (pCi/kg wet weight)
				^{89}Sr [b]	^{90}Sr [b]	^{137}Cs	^{137}Cs
Arctic caribou herd Anaktuvuk Pass, C–1	4/25	F	9	40	25	21.0×10^3	5.9×10^3
	4/25	F	10			9.5×10^3	
	4/25	F	[d]			18.0×10^3	
	4/25	F	9			5.4×10^3	
	4/25	M	2			19.0×10^3	
Nelchina caribou herd Dickey Lake, C–2	5/9	M	5	0	35	11.0×10^3	5.1×10^3
	5/9	M	9			12.0×10^3	
	5/9	F	5			8.3×10^3	
	5/9	M	4			8.3×10^3	
Peninsula caribou herd King Salmon, C–3	3/16	F	3	0	20	22.0×10^3	1.1×10^3
	3/16	F	4			17.0×10^3	
	3/16	F	9			9.1×10^3	
	3/16	F	[d]			25.0×10^3	
	3/16	F	5			17.0×10^3	
Shishmaref reindeer herd, Seward Peninsula, R–4	4/20	M	5	0	4	17.0×10^3	3.1×10^3
	4/20	M	4			17.0×10^3	
	4/20	M	4			13.0×10^3	
	4/20	M	3			17.0×10^3	
	4/20	M	3			13.0×10^3	
Nunivak Island reindeer herd, R–8	4/5	F	2	0	10	17.0×10^3	7.1×10^3
	4/5	M	5			13.0×10^3	
	4/5	F	5			22.0×10^3	
	4/5	M	4			20.0×10^3	
	4/5	F	5			19.0×10^3	
Nome reindeer herd, R–10	5/4	M	2	200	840	10.0×10^3	11.0×10^3
	5/1	M	5			19.0×10^3	
	5/5	M	5			14.0×10^3	
	5/5	M	2			20.0×10^3	
	5/4	F	4			17.0×10^3	

[a] Sampling locations are shown in figure 1.
[b] Composite of individual samples taken within herd.
[c] All results ≤ 5 pCi/kg wet weight are reported as 0.
[d] Ages not available.

and reindeer herds in Alaska that were sampled in the spring of 1968.

For the present program, samples are taken in the spring and fall from selected caribou and reindeer herds. Samples of muscle and rumen contents of five animals from each herd are collected during the sampling period. Hock joint bones from five animals are collected only from the Nome herd during the fall collection period. Muscle samples are analyzed individually and rumen content samples from each herd are composited before analysis for cesium–137 by gamma-ray spectroscopy. Muscle and bone samples from the individual herd are composited before analysis of strontium–89 and strontium–90. All samples are analyzed at the Public Health Service's Southwestern Radiological Health Laboratory in Las Vegas, Nev.

Strontium–89, strontium–90, and cesium–137 data are presented in table 1 for caribou muscle, reindeer muscle and rumen contents for the March–May 1968 collection period. The muscle data are of prime interest, since muscle is an important constituent of the diet for many Alaskan residents. A comparison of the muscle data is shown in table 2.

Table 2. Cesium–137 concentrations in caribou and reindeer muscle, spring 1967 and 1968

Herd	Average cesium-137 concentration (pCi/kg wet weight)	
	Spring 1967	Spring 1968
Arctic caribou	26×10^3 (May)	15×10^3 (April)
Nelchina caribou	14×10^3 (March)	10×10^3 (May)
Peninsula caribou	16×10^3 (April	18×10^3 (March)
Shishmaref reindeer	17×10^3 (May)	15×10^3 (April)
Nunivak reindeer	32×10^3 (April)	18×10^3 (April)
Nome reindeer	22×10^3 (April)	16×10^3 (May)

As can be seen in table 1, the cesium–137 range in muscle of individual samples within individual herds is quite large. For this reason it is very difficult to establish a definite trend. Table 2 does indicate that the cesium–137 levels in muscle during the spring of 1968 did not increase as compared to similar data in the

spring of 1967. A summary of the strontium–90 and cesium–137 concentrations in foodstuffs in Alaska (including reindeer and caribou meat) is contained in the December 1966 issue of *Radiological Health Data and Reports.*

Recent coverages in *Radiological Health Data and Reports:*

Period	Issue
October–November 1966	May 1966
March–May 1967	January 1968
August–October 1967	June 1968

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual. [1]

Summaries of data from the environmental radioactivity monitoring reports follow for the Atomics International and the Paducah Plant.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation," contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Atomics International [2] January–June 1968

North American Rockwell Corporation
Canoga Park, California

Atomics International, a division of North American Aviation, Incorporated, has been engaged in atomic energy research and development since 1946. The company designs, develops, and constructs nuclear reactors for central station and compact power plants and for medical, industrial, and scientific applications.

The company headquarters is located in Canoga Park, California, approximately 23 miles northwest of downtown Los Angeles. The 290-acre Nuclear Development Field Laboratory (Santa Susana Facility), equipped with extensive testing facilities for the support of advanced nuclear studies, is in Ventura County in the Simi Hills approximately 29 miles northwest of downtown Los Angeles. The location of the above sites in relation to nearby communities is shown in figure 1.

[2] Summarized from "Environmental Monitoring, semiannual report, January 1 to June 30, 1968" Atomics International, Division of North American Rockwell Corporation.

The basic concept of radiological hazard control at Atomics International encourages total containment of radioactive materials and, through rigid operational controls, minimizes effluent releases and external radiation levels. The environmental monitoring program provides a check on the effectiveness of radiological safety procedures and of engineering safeguards incorporated into facility design.

The environs of Atomics International headquarters and Nuclear Development Field Laboratory (NDFL) are surveyed monthly to determine the concentration of radioactivity in typical surface soil, vegetation, and water samples. In addition, continuous environmental air monitoring at the sites provides information concerning airborne particulate radioactivity.

Air monitoring

Environmental air sampling is conducted continuously at the headquarters and NDFL sites with automatic air samplers operating on 24-hour sampling cycles. Airborne particulate radioactivity is collected on HV–70 filter paper which is automatically changed at the end of each sampling period. The filter is removed from the sampler and counted after the radioactivity is allowed to decay for at least 72 hours.

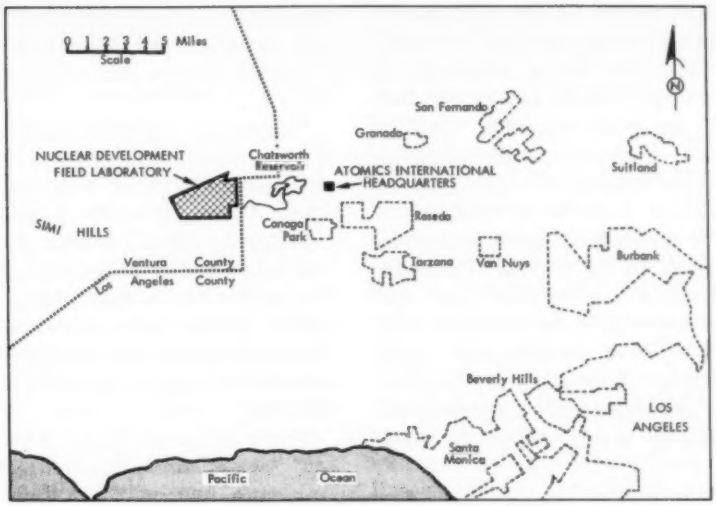

Figure 1. Atomics International facilities and vicinity

The volume of a typical daily environmental air sample is approximately 20 cubic meters. The average concentration of long-lived beta-gamma radioactivity on airborne particulates is presented in table 1 for 1967 and the first half of 1968.

Table 1. Beta-gamma radioactivity of airborne particulates, Atomics International

Location	1967		January-June 1968	
	Number of samples	Average concentration (pCi/m^3)	Number of samples	Average concentration (pCi/m^3)
Headquarters	712	0.39	301	0.48
NDFL	2,400	.40	1,062	.47

Water monitoring

Process water used at the NDFL is obtained from Ventura County Water District No. 10 and distributed onsite by the same piping system previously used when process water was supplied by onsite wells. Pressure is provided by elevated storage tanks, one 50,000-gallon and one 500,000-gallon tank onsite. While clinically potable, the water is not used for drinking. Bottled potable water is delivered by a vendor and is not analyzed. Water from the pipe system is sampled monthly at two locations. The average process water radioactivity concentration is presented in table 2.

Table 2. Well water radioactivity, NDFL site Atomics International

Type of radioactivity	1967		January-June 1968	
	Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Alpha	24	0.12	12	0.18
Beta-gamma	24	6.1	12	4.9

Water samples are also collected monthly at Chatsworth Reservoir which is operated by the Los Angeles City Department of Water and Power. Normally, one water sample is obtained from the lake surface and a second sample is obtained from the reservoir water supply inlet located on the north side of the lake. The average radioactivity for both surface and supply water samples is presented in table 3.

Table 3. Chatsworth Reservoir water radioactivity Atomics International

Sample	Type of radioactivity	1967		January-June 1968	
		Number of samples	Average concentration (pCi/liter)	Number of samples	Average concentration (pCi/liter)
Lake surface	Alpha	12	0.31	6	0.42
	Beta-gamma	12	8.1	6	7.9
Supply inlet	Alpha	12	.28	6	.15
	Beta-gamma	12	6.0	6	4.5

Surface discharged waters from NDFL facilities drain into holding reservoirs on adjacent property. When full, the main reservoir is drained into Bell Creek, a tributary of the Los Angeles River in the San Fernando Valley, Los Angeles County. Pursuant to the requirements of Los Angeles Regional Water Quality Control Board Resolution 66–49 of September 21, 1966, an environmental sampling station has been established in Bell Creek Canyon approximately 3.4 miles downstream from the south NARC boundary. Samples obtained and analyzed monthly, include stream bed mud, vegetation, and water. Average radioactivity concentrations in the main holding reservoir and Bell Creek samples are presented in table 4.

Table 4. Radioactivity in the Rocketdyne Reservoir [a] and Bell Creek, Atomics International, January–June 1968

Sample description (units)	Number of samples	Alpha radioactivity	Beta radioactivity
Reservoir Station 6 [a] (pCi/liter)	6	0.26	7.1
Reservoir Station 12 [a] (pCi/liter)	6	.58	8.4
Bell Creek mud (pCi/g)	5	.31	23
Bell Creek vegetation (pCi/g ash)	5	.35	171
Bell Creek water (pCi/liter)	5	.07	4.3

[a] Locations not shown on figure 1.

Soil and vegetation monitoring

Soil and vegetation are regularly sampled at 24 locations. Twelve sampling stations are located within the boundaries of Atomics International's sites and are referred to as "onsite" stations. The remaining 12 stations, located within a 10-mile radius of the sites, are referred to as "offsite" stations.

Surface soil types available for sampling range from decomposed granite to clay and loam. Samples are taken from the top half-inch layer of ground surface. The soil samples are packaged and sealed in plastic containers and returned to the laboratory for analysis. Radioactivity in soil samples is presented in table 5.

Vegetation samples obtained in the field are of the same plant type wherever possible, generally, sunflower or wild tobacco plant leaves. These types maintain a more active growth rate during the dry season than do most natural vegetation indigenous to the local area. Vegetation leaves are stripped from plants and transferred to the laboratory for analysis. Plant root systems are not routinely sampled. Radioactivity in vegetation samples is presented in table 6.

Table 5. Radioactivity in the soil, Atomics International

Area	Type of radioactivity	1967		January-June 1968	
		Number of samples	Average concentration (pCi/g)	Number of samples	Average concentration (pCi/g)
Onsite	Alpha	144	0.41	72	0.47
	Beta-gamma	144	28	72	25
Offsite	Alpha	48	.38	24	.50
	Beta-gamma	48	24	24	25

Table 6. Radioactivity in vegetation, Atomics International

Area	Type of radioactivity	1967		January-June 1968	
		Number of samples	Average concentration (pCi/g ash)	Number of samples	Average concentration (pCi/g ash)
Onsite	Alpha	144	0.61	72	0.55
	Beta-gamma	144	286	72	177
Offsite	Alpha	48	.38	24	.55
	Beta-gamma	48	413	24	273

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1967	March 1968
July–December 1967	June 1968

2. Paducah Plant [3] January–June 1968

Union Carbide Corporation
Paducah, Kentucky

The Paducah Plant is a government-owned gaseous diffusion plant operated by the Nuclear Division of the Union Carbide Corporation for the Atomic Energy Commission. The diffusion plant processes large quantities of relatively pure uranium compounds. The uranium hexafluoride manufacturing plant, a former source of diffusion plant feed, was placed on standby in June of 1964. Parts of the associated uranium metal foundry, usually on standby, are operated infrequently as the need arises. A decontamination and uranium recovery facility operates to prepare equipment for repair and to recover impure or scrap uranium materials. Depleted uranium metal is fabricated into shields, weights, ballasts, or other shapes on a nonroutine basis. The major sources of external penetrating radiation are the daughter products of uranium, thorium–234, and protactinium–234, which may be concentrated by uranium recovery processes or by uranium hexafluoride vaporization. The element, uranium can be a physiological hazard only if allowed to enter the body. The chemical toxicity of the uranium processed at the Paducah Plant overshadows any probable biological effects of radiation from this element, thus making it comparable as a physiological hazard to lead, mercury, or other well-known heavy metals.

Because of the necessity for health protection in process areas, the high intrinsic value of uranium, and the desire to maintain a wholesome relationship with neighboring communities and individuals, the Paducah Plant provides confinement and recovery systems at the plant. The environmental monitoring program provides for continuously sampling the air at four stations around the plant perimeter fence, and at five stations located approximately 1 mile outside this fence (figure 2). Big Bayou Creek water is sampled continuously, and grab samples are collected at five locations in the Ohio River. In addition, gamma radiation readings are taken each month at each of the air sampling stations with a Geiger-Mueller type meter at a distance of 3 feet above ground level.

Basic standards

The radiation protection standards observed at the Paducah Plant for exposure to radiation and radioactive materials, both for the in-plant work environment of employees and for offsite exposure of the general population, are those contained in Appendix 0524 of the AEC manual.

[3] Summarized from "Environmental Concentrations of Radioactive Materials Near the Paducah Plant—Report for the First Half of 1968."

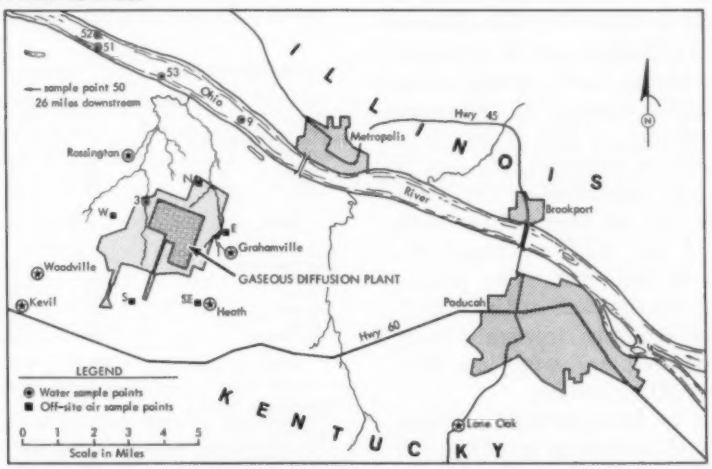

Figure 2. Sampling locations, Paducah Plant

The standards specify that the radiation or radioactive materials outside a controlled area, and which have resulted from operations within that controlled area, shall be such that it is improbable that any individual may receive a dose of external radiation greater than 0.5 rem in any year and that the average exposure of a suitable population sample may not exceed one-third of this dose. To meet this standard, the average concentration of radionuclides in air or water beyond a controlled area should not exceed one-tenth of the maximum permitted for occupational exposure of 168 hours per week. For the purposes of such control, the concentrations of such radionuclides in air or water may be averaged over periods of time up to 1 year.

Discussion

Data summarizing the environmental concentrations of radioactive materials in air and water and the gamma radiation levels in the vicinity of the Paducah Gaseous Diffusion Plant are presented in tables 7 through 10.

Air samples were collected continuously at each of the four stations at the plant perimeter fence and at five stations about 1 mile outside the plant. Air is filtered at 0.3 cfm through 2-inch diameter membrane filters which are replaced weekly and counted for alpha and beta radioactivity.

The average alpha-particle count—interpreted as uranium, the most likely source of radioactivity—of the 234 air samples collected during the first half of 1968 was less than 1 percent of the AEC standard set for individuals residing in the vicinity of a controlled area. The average beta-particle count of the same samples was 0.02 percent of the standard.

The average uranium analyses of weekly water samples collected continuously from the Big Bayou Creek during the first half of 1968 was 0.02 percent of the AEC standard for water beyond a controlled area. The results of the uranium analyses for each of the 6 grab samples collected at monthly intervals from the Ohio River below the plant, were less than 0.01 percent of the AEC standard.

The concentration of beta-particle emitters in the Big Bayou Creek averaged less than 0.5 percent of the AEC standard for the decay products of uranium–238. The beta radioactivity of the Ohio River was less than 0.5 percent of the standard for uranium–238 decay products.

External gamma radiation in the vicinity of the Paducah Plant averaged 0.02 mR/hr at all sampling stations for January–June 1968.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1967	January 1968
July–December 1967	May 1968

Table 7. Uranium concentrations in outdoor air samples Paducah Plant, January–June 1968

Sample location [a]	Number of samples	Uranium alpha radioactivity [b] (pCi/m³)		
		Maximum	Minimum [c]	Mean [d]
At plant perimeter fence:				
North	26	0.04	<0.02	<0.02
East	26	.04	< .02	< .02
South	26	.02	< .02	< .02
West	26	.02	< .02	< .02
Total	104	0.04	<0.02	<0.02
About 1 mile outside plant perimeter fence:				
North	26	.02	< .02	< .02
East	26	.02	< .02	< .02
South	26	.02	< .02	< .02
West	26	.03	< .02	< .02
Southeast	26	.03	< .02	< .02
Total	130	0.03	<0.02	<0.02

[a] See map in figure 1.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 alpha dis/sec.
[c] The minimum detectable concentration of uranium in air is 0.02 pCi/m³.
[d] The AEC standard for natural uranium in air released to the environs beyond a controlled area is 2 pCi/m³.

Table 8. Beta radioactivity in outdoor air samples Paducah Plant, January–June 1968

Sample location [a]	Number of samples	Beta radioactivity (pCi/m³)		
		Maximum	Minimum [b]	Mean [c]
At plant perimeter fence:				
North	26	0.36	<0.1	0.20
East	26	.43	< .1	.20
South	26	.43	< .1	.15
West	26	.57	< .1	.20
Total	104	0.57	<0.1	0.19
About 1 mile outside plant perimeter fence:				
North	26	.66	< .1	.22
East	26	.69	< .1	.20
South	26	.72	< .1	.24
West	26	.61	< .1	.21
Southeast	26	.49	< .1	.21
Total	130	0.72	<0.1	0.22

[a] See map in figure 1.
[b] The minimum detectable amount of beta-particle emitters in air is 0.1 pCi/m³.
[c] The AEC standard, applicable to this table is 1×10^3 pCi/m³, which is the concentration limit of thorium-234, the daughter product of uranium-238. Insignificant amounts of other daughters are present in freshly refined uranium.

Table 9. Concentrations of uranium in water Paducah Plant, January–June 1968

Sample location [a]	Number of samples	Uranium [b] (pCi/liter)		
		Maximum	Minimum [c]	Mean [d]
Big Bayou Creek 3	26	11	<1	3
Ohio River	6	< 1	<1	<1
Composite of 50, 51, 52, and 53	6	2	<1	<1

[a] See map in figure 1.
[b] As defined in NBS Handbook 69, paragraph 3.2, a microcurie of recently extracted normal uranium corresponds to 7.57×10^4 dis/sec.
[c] The minimum detectable uranium in water is 1 pCi/liter.
[d] The AEC standard for natural uranium in water beyond a controlled area is 2×10^4 pCi/liter.

Table 10. Concentration of beta-particle emitters in water, Paducah Plant, January–June 1968

Sample location [a]	Number of samples	Beta-particle emitters (pCi/liter)		
		Maximum	Minimum [b]	Mean [c]
Big Bayou Creek 3	26	200	<100	<100
Ohio River 9	6	400	<100	100
Composite of 50, 51, 52, and 53	6	<100	<100	<100

[a] See map in figure 1.
[b] The minimum detectable amount of beta-particle emitters in water is 100 pCi/liter.
[c] The AEC standard for the immediate daughter products of uranium in water released to the environs is 2×10^4 pCi/liter.

Reported Nuclear Detonations, November 1968

The U.S. Atomic Energy Commission announced five underground nuclear tests conducted at its Nevada Test Site during November 1968.

The tests of November 3, 15, 20 and 22 were of low yield (less than 20 kilotons TNT equivalent). The test of November 4 was in the low-intermediate (20 to 200 kilotons TNT equivalent) yield range.

On November 7, 1968, it was announced by the Commission that the United States had recorded seismic signals originating from the Soviet northern testing area in the Novaya Zemlya region. The signals were equivalent to those of a nuclear test in the lower end of the intermediate yield range (200 kilotons to one megaton TNT equivalent).

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

CESIUM–137 CONCENTRATIONS IN ALASKANS DURING THE SPRING OF 1967. *H. J. L. Rechen, R. L. Mikkelsen, O. G. Briscoe, and J. F. Steiner, Jr. Radiological Health Data and Reports, Vol. 9, December 1968, pp. 705–717.*

During April and May 1967, cesium–137 concentrations were measured by the National Center for Radiological Health, Public Health Service, in 1,334 residents of 13 Alaskan villages and cities where caribou and reindeer are major sources of meat. Unshielded 7.5 x 7.5 cm NaI (Tl) scintillation detectors, held in the lap, were used for subjects of both sexes, from 4 to 91 years old, weighing 16 to 100 kilograms. The maximum cesium–137 concentrations ranged from 16.58 to 20.76 nCi/kg for males and from 12.92 to 18.21 nCi/kg for females.

Cesium–137 concentrations were highest in Ambler, Selawik, Noorvik, Shungnak, and Anaktuvuk Pass, intermediate in Shishmaref, Noatak, Mekoryuk, Egegik and Teller, and lowest in three coastal cities where whaling is done (Wainwright, Point Hope and Barrow).

The Bureau of Indian Affairs school lunch program, where practiced, did not appear to reduce significantly the cesium–137 concentrations in children. Average concentrations in men who were measured both years at Anaktuvuk Pass dropped 37.5 percent from 1966 to 1967; Selawik males showed a 15.7 percent decrease, while cesium–137 concentrations in adult male residents of Egegik increased 2 percent.

The "radiation dose index," defined in the report for the highest individual value measured in 1967 was 0.17 rad/year, in an 82 kg man whose cesium–137 concentration was 21 nCi/kg. The guidance published by the Federal Radiation Council suggests that no protective action except for continued surveillance appears to be necessary at this time.

KEYWORDS: Alaska, caribou, cesium–137, radiation dose index, reindeer.

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